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Summary of Threatened and Endangered Bat-related Restrictions on Military Training, Testing, and Land Management

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Final Report

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ABSTRACT: The Indiana bat, gray bat, lesser long-nosed bat, and Hawaiian hoary bat are all protected as endangered species throughout their ranges within the United States. One or more of these species has been documented to occur on at least 19 installations where the Army trains. This report evaluates the potential for these four endangered bat species to impact military training activities, based on species conservation requirements, training requirements, and documented restrictions put in place by the U.S. Fish and Wildlife Service. This report includes basic information about each species' life requirements, occurrences on or near Army lands, known training restrictions that have been instituted in support of species conservation, and a brief risk analysis of the potential for development of new data leading to additional future restrictions. Based on the risk analysis, this report recommends research priorities for the Army that would improve the scientific basis for evaluating the risk of military training to these species, and thus, the risk of species conservation impacting Army preparedness.

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Preface

This study was conducted for Headquarters, U.S. Army Corps of Engineers under project A896, "Base Facility Environmental Quality"; Work Unit 00AB41, "Research Military Training Effects on High Priority Species." The technical monitor was Bill Woodson, DAIM-ED-N.

The work was performed by the Land and Heritage Conservation Branch (CN-C) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The Principal Investigator was Matthew G. Hohmann. Part of this work was done by Anne-Marie Shapiro of the Center for Ecological Management of Military Lands, Colorado State University. The technical editor was Gloria J. Wienke, Information Technology Laboratory. Dr. Lucy A. Whalley is Chief, CEERD-CN-C, and Dr. John T. Bandy is Chief, CEERD-CN. The associated Technical Director was Dr. William D. Severinghaus, CEERD-CV-T. The Director of CERL is Dr. Alan W. Moore.

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1 Introduction

Background

When a Biological Opinion is written by the U.S. Fish and Wildlife Service (USFWS), scientific knowledge about species biology is combined with descriptions of desired or ongoing human activity to ascertain the degree of threat posed to the species by human actions. If adverse effects to the species seem possible, specific restrictions on human activity are put into place through the Biological Opinion process. When endangered species exist on Army installations, restrictions are often requested or required by the USFWS that alter or reduce training for military preparedness. Additional responsibilities are often placed on the Army as well, such as research, monitoring, and habitat management actions. Understandably, training restrictions in particular, as well as other conservation requirements, are of great importance to the Army since these issues effect the primary mission of the military.

Four endangered bats have been documented to occur on at least one Army installation in the United States. Two species, the Indiana bat (*Myotis sodalis*) and the *gray bat* (Myotis grisescens), are insectivorous, migratory, and occur in the Midwest and eastern sections of the country. The nectivorous lesser long-nosed bat (*Leptonycteris curasoae*) summers in Arizona. The insectivorous Hawaiian hoary bat (*Lasiurus cinereus semotus*) has been documented on a small number of the Hawaiian Islands. The first three species roost in caves during part or all of their annual life cycle. The Indiana bat and the Hawaiian hoary bat utilize vegetation for roosting, leading to a highly dispersed pattern of occurrences across a landscape. Three of the species migrate long distances annually, while the Hawaiian hoary bat may not. The Army is required to consider the needs of these species for shelter, food, behavioral integrity (such a flight behaviors, breeding behaviors, etc.) and physiological safety. The presence of these species has led to changes and restrictions on military training on many installations. Restrictions have been enforced that alter training locations, frequencies, and the weapons and/or materials used in training exercises at specific locations at specific times. The Army could benefit from understanding the actual extent to which legal restrictions impact the training mission due to the presence of endangered bat species, and from focusing future research funds toward questions that are likely to delineate potential future conflicts

between the mission and the biological and conservation requirements of these bat species. This report provides information on both topics.

Objective

The first objective of this report is to collect and synthesize information related to the biological and conservation requirements of four endangered bat species, along with the documented, likely, or potential restrictions to the military training mission on Army lands based on the presence of these species. The second objective is to provide recommendations for future Army research that will be helpful in delineating the potential for future conflict between these endangered bat species and the Army mission.

Approach

This report is limited to scientific and legal information related to four bat species, the Indiana bat, gray bat, lesser long-nosed bat, and Hawaiian hoary bat, and the Army installations on which they have been documented to exist. Dozens of military installations and USFWS Regional and Field Offices were canvassed for relevant Biological Assessments, Biological Opinions, Environmental Assessments, Environmental Impact Statements, and Endangered Species Management Plans. Although this information-gathering effort was not exhaustive, the restrictions identified within the resources obtained are likely to be representative of those imposed on military training, testing, and land management.

Scope

This document summarizes basic biological knowledge about each species, known or potential threats to each species, the overlap between species occurrences and Army training lands, and documented restrictions on human activity that are relevant to Army training actions. The biological information includes basic habitat requirements, behavioral patterns, such as migration, breeding and foraging behaviors, and known sensitivities to noises, human activity, and chemical stressors. This report includes discussions about potential human impacts such as habitat alteration; military-unique chemicals; pesticides; noise from weapons, vehicles and aircraft; and disturbance of normal behavior through mounted or dismounted training exercises. Documented restrictions that have been mandated by the Fish and Wildlife Service in published Biological Opinions are included. Research recommendations related to the four stated species and the listed potential impacts are presented.

Mode of Technology Transfer

This information will be provided to installations that have bat populations.

This report will be made accessible through the World Wide Web (WWW) at URL: http://www.cecer.army.mil

2 Species Biology

Knowledge of the life history requirements of the four endangered bat species (Indiana bat, gray bat, lesser long-nosed bat, and Hawaiian hoary bat) assists in the evaluation of potential risks to the species from military training and land management activities, thereby providing a basis upon which to assess current and potential bat-related restrictions on military installations.

The Biology of Hibernation and Swarming

Indiana Bat

Although Indiana bats hibernate in caves and mines throughout the karst areas of the eastern United States (Figure 1), hibernacula must provide specific climatic conditions, including: stable winter temperatures below 59 °F (10 °C, optimal temperature is 37.4 °F to 42.8 °F [3 °C to 6 °C]) and relative humidities above 74 percent (USFWS 1999a). Stable low temperatures allow the bats to maintain a low rate of metabolism and conserve fat reserves through the winter until spring (Humphrey 1978, Richter et al. 1993). More than 50 percent of the species is believed to hibernate in only nine caves or abandoned mine shafts (USFWS 1999a). Having hibernating populations of at least 30,000 individuals, these nine sites have been classified as Priority I hibernacula. The remaining population is believed to hibernate in the Priority II and Priority III hibernacula, which have 500 to 30,000 individuals and less than 500 individuals, respectively (Figure 1).

Indiana bats select roosts within hibernacula that best meet their needs for cool temperatures; in many hibernacula, these roosting sites are often near an entrance, but may be deeper in the cave or mine if that is where the cold air flows and is trapped (Tuttle and Stevenson 1978). Indiana bats typically hibernate in dense clusters, with bat densities ranging from 300 to approximately 500 per square foot (Clawson et al. 1980).

By late August, Indiana bats begin to disperse from maternity colonies, migrate to their hibernacula, and engage in swarming behavior. Most Indiana bats return to the same cave or localized cave cluster each fall (Menzel et al. 2001). Swarming occurs when bats congregate at the hibernacula, fly into and out of the site, but roost in trees outside. Swarming continues for several weeks, during which time the bats

mate and replenish fat reserves prior to hibernation. Depending on local weather conditions, swarming may continue through October or November. Males generally remain active longer than the females during this pre-hibernation period, but all Indiana bats are usually hibernating by late November (USFWS 1999a).

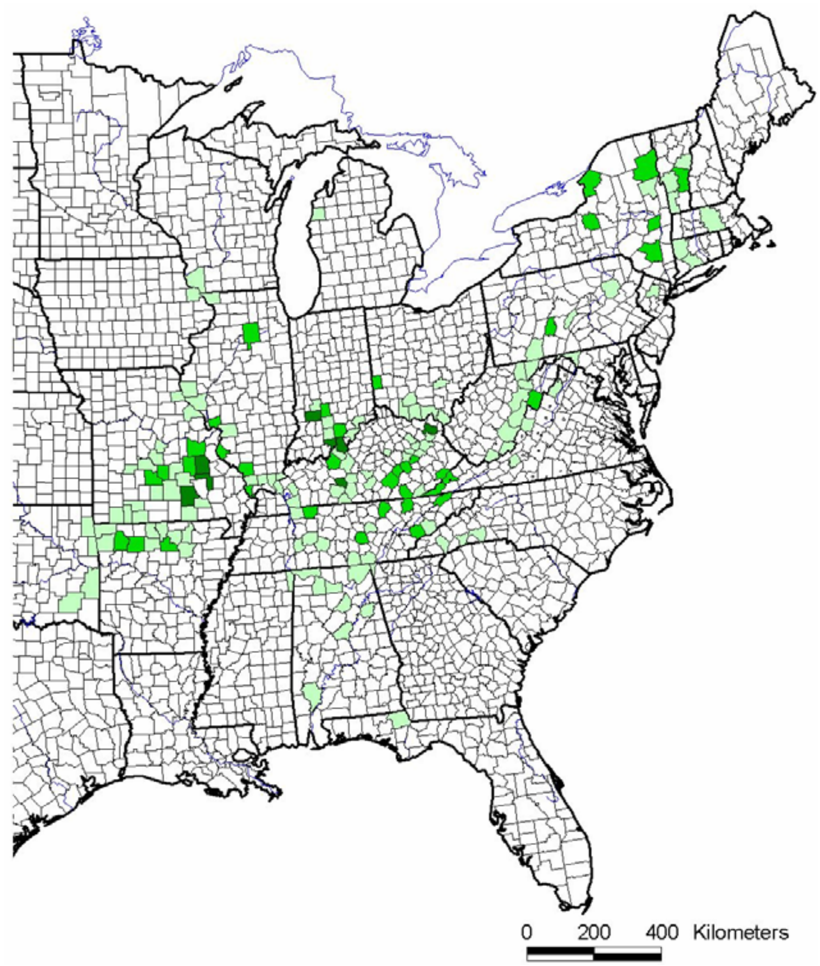

Figure 1. Counties in which Indiana bat hibernacula have been documented. Counties where Priority I, II, and III hibernacula are known to occur are shown in dark, medium, and light green, respectively.

Three studies have documented the use of drier, upland habitats for foraging during the swarming period, as compared to the many studies of foraging in bottomland forest during the maternity season (reviewed by Menzel et al. 2001). During September in West Virginia, males have been found roosting in trees near ridge tops within 3.5 miles (5.6 km) of their hibernacula, often switching roost trees from day to day (Craig Stihler, Biologist, West Virginia Division of Natural Resources, 1996, cited in Menzel et al. 2001). Similarly, male bats have been found roosting primarily in dead trees on upper slopes and ridge tops during the fall in Kentucky (Kiser and Elliot 1996). In Missouri, swarming Indiana bats foraged up to 4 miles (6.4 km) from roost sites (Rommé et al.2002). Limited research suggests foraging distances become reduced to an area within 1.5 miles (2.5 km) of the hibernaculum, by some

time in October. For example, in Kentucky, male Indiana bats radiotracked during October were found to forage up to 1.7 miles (2.7 km) from their roost sites, and to roost in trees between 0.5 and 1.5 miles (0.8 and 2.4 km) from the hibernaculum (Kiser and Elliot 1996). Recently, Tennessee and Indiana Field Offices of the USFWS issued guidelines for activities within 5 miles (8.05 km) of Indiana bat hibernacula when Indiana bats may be present (USFWS 2004).

Gray Bat

The gray bat is a cave-dwelling species of the south-central United States. Because the gray bat requires very specific conditions, most caves are rendered unsuitable as hibernacula. During winter, approximately 95 percent of the entire species population hibernates in only nine caves. Figure 2 shows the counties where Priority I gray bat hibernacula have been documented. Gray bat hibernacula are generally deep, vertical structures with large rooms that trap cold air. The bats hang in massive mats containing several thousand densely packed individuals (Hall 1962, Gore 1992).

In early September, gray bats initiate swarming behavior, which includes breeding and increased feeding in preparation for hibernation. Females enter hibernation from early September until early October. Males and juveniles continue foraging in the vicinity of the hibernacula, but most are in hibernation by early November (Tuttle and Stevenson 1977).

Hawaiian Hoary Bat

Occurring on six islands of the climatically stable Hawaiian archipelago, the Hawaiian hoary bat is not known to hibernate. However, some evidence suggests its activity may vary seasonally. Kepler and Scott (1990) suggested that reduced activity in the winter could be explained if bats entered torpor, and increases in numbers of observations during other times of year could be caused by the emergence of newly volant young-of-the-year. Tefler (1992) noted decreases in bat sightings between May and September on Kauai. Several other researchers (Menard 2001, Fullard 1989, and Reynolds et al. 1997) have also mentioned seasonal variation in bat observations, but the nature and timing of this variation is unclear.

Lesser Long-nosed Bat

The lesser long-nosed bat does not hibernate or exhibit swarming behavior.

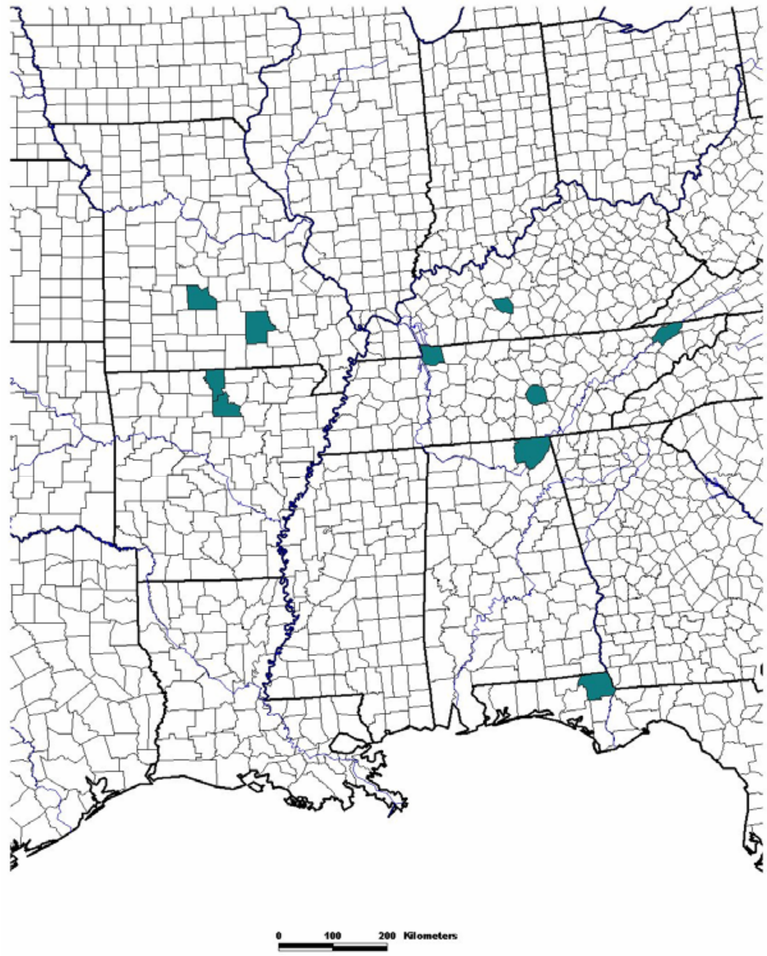

Figure 2. Counties where Priority I (>50,000 individuals) gray bat hibernacula have been documented.

Summertime Habitat and Reproductive Biology

Indiana Bat

Researchers continue to learn about the summer habitat needs of this endangered species. The perception of what constitutes suitable habitat and the amount required has evolved over the past decade. Early researchers considered floodplain and riparian forests to be the primary roosting and foraging habitats used during the summer by the Indiana bat (Humphrey et al. 1977). Although these forest types are unquestionably important, more recent studies have shown that upland forests are also used by Indiana bat (Clark et al. 1987, Gardner et al. 1991b, Callahan et al. 1997). Old fields and pastures with scattered trees have also been shown to provide roosting and foraging habitat (Gardner et al. 1991b). A workshop of Indiana bat experts held in May 1997 reviewed the contents of a 1995 Indiana bat habitat suitability (HSI) model (Rommé et al.1995) and made changes that were deemed impor-

tant. The workshop participants altered the earlier model by including many more vegetation cover types in the revised model. Instead of assuming that forested cover types provide the only food source, the newer model includes row crop, pasture, hay meadow, wetlands, water (i.e., reservoir, lake, or stream), early successional habitat, upland deciduous forest, riparian/floodplain deciduous forest, and coniferous forest. Furthermore, these experts postulated that foraging habitat is of highest quality when a landscape of 0.77 sq miles (2 sq km) includes four different cover types, since that would provide a more diverse food supply of insect emergence patterns (Farmer et al. 2002). The workshop participants quantified the value of landscape diversity by setting the highest value on landscapes (of 0.77 sq mi [2 sq km]) containing between 20 and 60 percent forest cover type (Farmer et al. 2002). However, results of testing the resulting, revised model revealed that landscape cover type did not assist in predicting locations with Indiana bats, except to point out that landscapes with more forested cover were likely to have more suitable roost trees (and this was the most important factor in their modeling exercise; Farmer et al. 2002). This result concurred with the findings of Miller et al. (2002) in which, again, the likelihood of large-diameter (potential roost) trees was by far the most important predictive factor in finding occupied summer habitat, regardless of surrounding landscape composition (Miller et al. 2002).

Throughout the species' maternity range (Figure 3) presence in a particular area may be governed by the availability of natural roost structures, which are primarily standing dead trees with loose bark. The suitability of any tree as a roost site is believed to be determined by (1) its condition (dead or alive); (2) the quantity of loose bark; (3) its solar exposure and location in relation to other trees; and (4) its spatial relationship to water sources and foraging areas (USFWS 1999a).

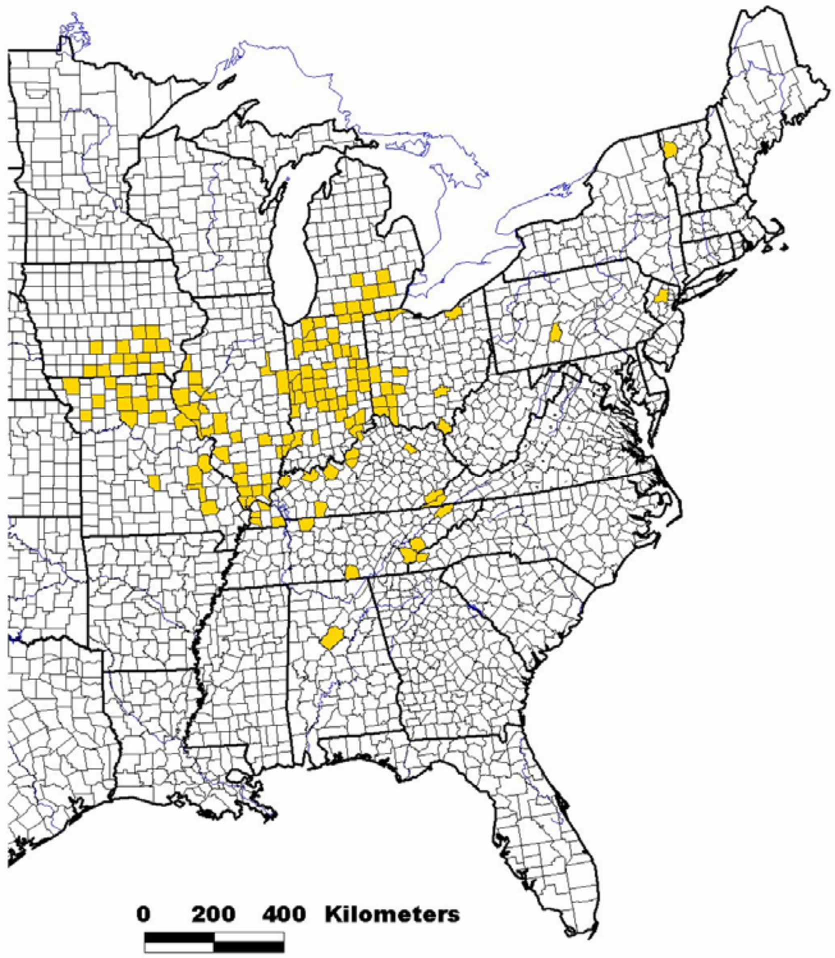

Figure 3. Counties where pregnant or lactating Indiana bats have been observed.

A number of tree species have been reported to be used as roosts by Indiana bats. These include: American beech (*Fagus grandifolia*), ashes (*Fraxinus* spp.), black gum (*Nyssa sylvatica*), black locust (*Robinia pseudoacacia*), cottonwood (*Populus deltoides*), elms (*Ulmus* spp.), hickories (*Carya* spp.), maples (*Acer* spp.), oaks (*Quercus* spp.), pines (*Pinus* spp.), sassafras (*Sassafras albidum*), sourwood (*Oxydendrum arboreum*), sweet birch (*Betula lenta*), and yellow buckeye (*Aesculus octandra*) (Cope et al. 1974, Humphrey et al. 1977, Gardner et al. 1991a,b, Kurta et al. 1993, Rommé et al. 1995, Kiser and Elliott 1996, Kurta et al. 1996, Callahan et al. 1997). Morphological characteristics of the bark of several trees make them particularly suitable as roosts for Indiana bats. When dead, senescent, or severely injured (e.g., by lightning) these trees possess bark that springs away from the trunk upon drying. Additionally, the shaggy bark of some living hickories (*Carya* spp.) and large white oaks (*Quercus alba*) also provide roost sites. The persistence of peeling bark varies with the tree species and the severity of environmental factors to which it is subjected. While some tree species are undoubtedly more often suitable as roosting habitat, structure (exfoliating bark with space for bats to roost between the

bark and the bole of the tree) is probably more important than the species of the tree (USFWS 1999a).

Indiana bat maternity colonies, which are typically fewer than 100 females, commonly use multiple roosts. Kurta et al. (1996) studied a maternity colony in northern Michigan over a 3-year period and noted that bats changed roost trees an average of every 2.9 days and that the number of roosts used by the colony ranged from 5 to 18. Other studies have shown that females in maternity colonies may use as few as 2, or as many as 33 roosts (Humphrey et al. 1977, Gardner et al. 1991a, Garner and Gardner 1992, Callahan 1993, Kurta et al. 1993, Rommé et al. 1995). A maternity colony may use several roosts up to 5 miles (8.05 km) apart (Kurta et al. 2002). Female bats often move from one roost to another in response to changes in environmental conditions (temperature and precipitation) or when a particular roost becomes unavailable (Gardner et al. 1991a, Callahan et al. 1997). Therefore, the importance of an individual roost site may not be as important as some researchers have suggested (Humphrey et al. 1977), and the Indiana bat may be more adaptable concerning roosting habitats than previously believed. Although the species appears to be adaptable, by making use of available roosts, it is apparent that a variety of suitable roosts should be available within a colony's occupied roosting area to ensure the continuance of the colony in a particular area (Kurta et al. 1993, Callahan et al. 1997).

The configuration and spatial extent of a colony's regular use area is probably determined by the availability of suitable roosts. In general, most roost trees used by a maternity colony are close to one another. The distances between roosts occupied by bats within a single maternity colony have been found to range from just a few meters to as great as several miles (Callahan 1993, Callahan et al. 1997). Thermoregulation may be a factor in roost site selection. Therefore, exposure to sunlight and location relative to other trees are likely important factors in suitability and use. Because cool temperatures can delay the development of fetal and juvenile young (Racey 1982), selection of maternity roost sites may be critical to reproductive success. Roosts are generally not surrounded by a closed canopy and can be warmed by solar radiation, thus providing a favorable microclimate for the growth and development of young during normal weather. Additionally, dead trees with east-southeast and south-southwest exposures may also provide enough solar radiation to warm nursery roosts effectively. Primary roosts (i.e., those occupied by more than 30 bats, after Callahan 1993 and Callahan et al. 1997) in some species of living trees (e.g., shagbark hickory [*Carya ovata*]), on the other hand, may provide better protection from rain and other unfavorable environmental conditions because the greater thermal mass of these live trees can maintain more favorable temperatures for roosting bats during brief cool periods (Humphrey et al. 1977). The tight bark of these trees is believed to shield bats from the encroachment of water into the roost

during rain events (Callahan et al. 1997). Snags exposed to direct solar radiation seem to be used most frequently by Indiana bats as summer roosts, followed by snags not fully exposed to solar radiation and live trees not fully exposed (Callahan 1993). Alternate roosts (i.e., those occupied by fewer than 30 bats, after Callahan 1993 and Callahan et al. 1997) tend to be more shaded, are frequently within forest stands, and are selected when temperatures are above normal or during periods of precipitation. Shagbark hickories again seem to provide particularly good alternate roosts because of the factors listed above. Roost site selection and use may differ between the northern and southern parts of the species' range, but, to date, such analyses have not been undertaken (USFWS 1999a, but see Britzke et al. 2003).

Primary roost trees have been found to range in size from 12.2 to 29.9 in. (31 to 76 cm) diameter at breast height (dbh; summarized in Rommé et al. 1995). Miller (1996) compared Indiana bat habitat variables for sites in northern Missouri and noted that significantly larger trees (>12 in. [30.5 cm] dbh) were found where reproductively active Indiana bats had been netted than at sites where bats had not been captured. Alternate roost trees also tend to be large, mature trees, but the range in size is somewhat wider than that of primary roosts (7 to 32.7 in. [18 to 83 cm] dbh) (Rommé et al. 1995).

Because some characteristics of roosting habitat preferred by Indiana bats are ephemeral, it is difficult to generalize or estimate their longevity due to the many factors that influence them (e.g., bark may fall off completely or the snag may fall over). Although roosts may be habitable for only 1 to 2 years under "natural conditions" for some tree species (Humphrey et al. 1977), others with good bark retention, such as slippery elm (*Ulmus fulva*), cottonwood, green ash (*Fraxinus pennsylvanica*), and oaks, may provide roosting habitat for 4 to 8 years (Gardner et al. 1991a, Callahan et al. 1997).

Indiana bats exhibit varying degrees of site fidelity to summer colony areas, roosts, and foraging habitat. Females have been documented returning to the same roosts from one year to the next (Bowles 1981, Humphrey et al. 1977, Gardner et al. 1991a,b, Callahan et al. 1997). Kurta et al. (1996), however, noted that individuals in a maternity colony in northern Michigan "were not highly faithful to a particular tree." In Illinois, male Indiana bats exhibited some site fidelity to summering areas they had occupied during previous years (Gardner et al. 1991b).

Most maternity records for the Indiana bat have originated in the Midwest (southern Iowa, northern Missouri, northern Illinois, northern Indiana, southern Michigan, and western Ohio). The first maternity colony was found in this region, and most studies of Indiana bat maternity habitat have been conducted here also. Although the woodlands in this glaciated region are mostly fragmented, the region has

a relatively high density of maternity colonies. Today, small bottomland and upland forested tracts with predominantly oak-hickory forest types and riparian/bottomland forests of elm-ash-cottonwood associations exist in an otherwise agriculturally dominated (nonforested) landscape (USFWS 1999a). Unglaciated portions of the Midwest (southern Missouri, southern Illinois, and southern Indiana), Kentucky, and most of the eastern and southern portions of the species' range appear to have fewer maternity colonies per unit area of forest. However, this may be an artifact in comparing these areas with the highly fragmented Midwestern forests (USFWS 1999a).

Data on male summertime habitat use is limited. Whitaker and Brack (2002) radio tagged four adult males in Indiana. Each bat used at least 2 and as many as 5 roost trees; the total number of trees recorded as roost trees was 12. These roosts included four American elms (*Ulmus Americana*), three pines, two white oaks, two northern red oaks (*Quercus rubra*) and one shagbark hickory. Average diameter at breast height was 15 ± 6 (SD) in. [38.1 ± 15.3 (SD) cm], and average canopy closure was 49 ± 2.3 percent. Nine of the 12 trees were dead, with 10 to 70percent of the bole covered in exfoliating bark. The telemetry study estimated the home ranges of these four male bats to range from 143.3 to 988.4 acres (58 to 400 ha), with a mean of 375.6 acres (152 ha). Roosts were found in riparian forests and upland forests. Whitaker and Brack (2002) also found hundreds of male Indiana bats roosting within hibernacula (caves) in the summer, and concluded that males do not migrate very far from hibernacula in the areas sampled.

Gardner et al. (1990) reported average home range sizes vary from about 70 acres (28.3 ha) for juvenile males to more than 525 acres (212.5 ha) for post-lactating adult females. Roosts occupied by individuals range from 0.3 miles (0.5 km) to more than 1.6 miles (2.6 km) from preferred foraging habitat, but are generally within 1.2 miles (1.9 km) of water (e.g., stream, lake, pond, natural or manmade water-filled depression; Gardner et al.1990).

Gray Bat

Within the gray bat's summer range (Figure 4), colonies typically inhabit home ranges that contain several roosting caves scattered along a river or reservoir edge. Females utilize the warmest caves, usually within 1 kilometer of a river or reservoir, whereas males and juveniles roost in more peripheral caves (USFWS 1982). Young are born in late May or early June, and are volant (able to fly) in 20 to 35 days (USFWS 1982). By August, all of the juveniles are volant and there is a general mixing and dispersal of the colony over the summer range.

Reproductive females must maintain a high body temperature at their relatively cool roosts, especially during the period of lactation from late May to early July. Maintaining a high body temperature requires larger amounts of energy, and during the period of peak demand, when young are roughly 20-30 days old, individual females sometimes feed continuously for more than 7 hours during a single night (USFWS 1982). For newly volant young, growth rates and survival are inversely proportional to the distance from their roost to the nearest over-water foraging habitat (Tuttle 1976a). Although mothers continue to nurse their young for a brief period after the young learn to fly, juveniles are apparently left to learn how and where to hunt on their own (Tuttle and Stevenson 1977).

Hawaiian Hoary Bat

Pregnant females have been documented on Hawaii and Kauai, but are not known from the other six islands where the species has been found (Kepler and Scott 1990). It is thought that each female gives birth to two young, as in the mainland hoary bat. Breeding probably occurs most frequently in September and October, with young born in May or June. It is not known whether or not this species experiences delayed fertilization, which is common among many mainland insectivorous bats, such as the Indiana bat and the gray bat. Lactating females have been captured in late June and early August. Post-lactating females have been caught between September and December (Tomich 1986a, Kepler and Scott 1990).

The Hawaiian hoary bat is a solitary species that roosts among foliage in trees. The degree of fidelity to roost sites is unknown. Jacobs (1993a) documented two radio-tagged bats using the same roost sites for a 2-week period, but Kunz (1982) suggested that roost site fidelity might vary seasonally and with reproductive condition. It is possible that bats return to a roosting area rather than a specific roost location.

Whether native vegetation is required by, or is important to, Hawaiian hoary bats is not known. The species has been documented to forage in open fields near nonnative or native vegetation, over ocean bays near the shore, over lava flows, and at streams and ponds (Baldwin 1950, Jacobs 1993b, 1994, Kujioka and Gon 1988, Kepler and Scott 1990, Reynolds et al. 1997). Kepler and Scott (1990) found that bats were most frequently observed in association with nonnative vegetation, with relatively few occurring in native vegetation.

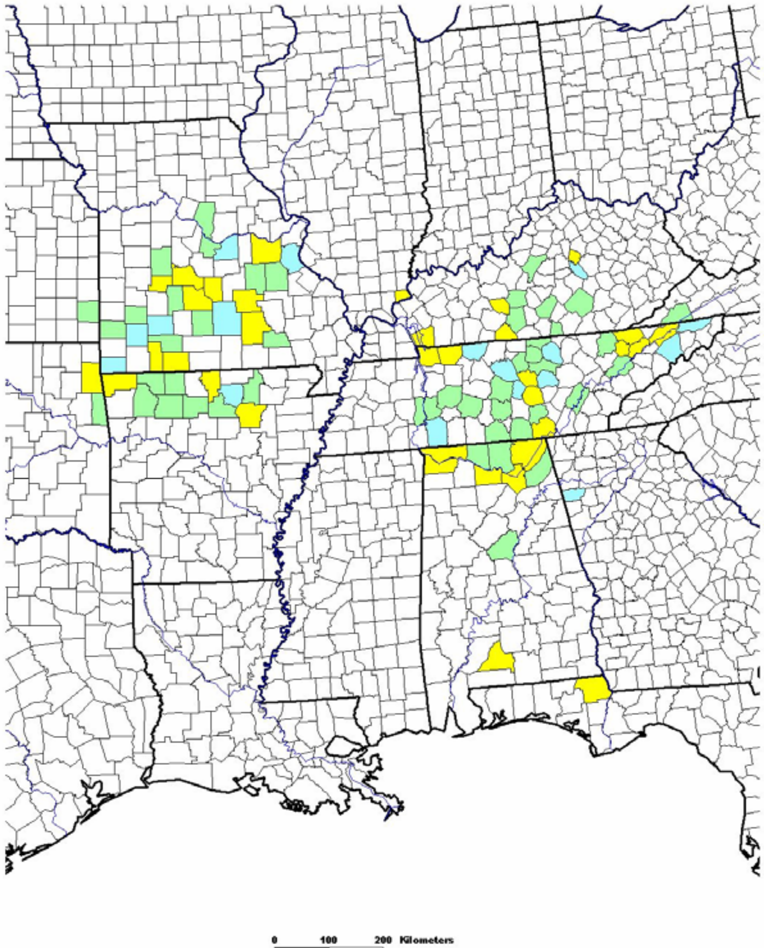

Figure 4. Counties where gray bat maternity caves are known to occur. Yellow=Priority I [>50,000], green=Priority II [25,000-50,000], blue=Priority III [<25,000]).

In contrast, Fullard (1989) stated that the only two locations on Kauai where bats were consistently observed were near native forests, and that he rarely found them in towns or over open fields. He concluded that the Hawaiian hoary bat was uncommon and found primarily in open wet areas near forests (for example, at ocean outlets of forested rivers), and only occasionally in drier areas. Jacobs (1994) also found that Hawaiian hoary bats on Hawaii are more frequently associated with native vegetation, and that native ohia trees (*Meterosideros polymorpha*) were used frequently by two radio-tagged bats as roost sites (Jacobs 1993a). However, also on Hawaii, Reynolds et al. (1997, 1998) found no significant difference in the numbers of bats detected in native, mixed, or alien forest types. Roosting has been documented in numerous tree species (Baldwin 1950, Bryan 1955, Kramer 1971). Tomich (1986b) stated that the Hawaiian hoary bat is "highly unselective in the kind of tree it selects for roosting," and asserted that replacement of native tree species with introduced species may not present a significant threat to populations. However, there is no indication that he gave any consideration to the potential im-

pact of nonnative vegetation on insect abundance or biodiversity when making this assertion.

Lesser Long-nosed Bat

The lesser long-nosed bat is known to occur in southern Arizona and extreme southwestern New Mexico from late April until as late as October 20 (Cockrum and Petrysyn 1991, Sidner 1999). The bat has only rarely been recorded outside of this time period in Arizona (USFWS 1997, Hoffmeister 1986). It resides in New Mexico only from mid-July to early September (Hoyt et al. 1994). Maternity roost sites, which include caves, mines or abandoned buildings, are known from Arizona and Mexico. According to USFWS (1997), the twelve major maternity roosts in Arizona and Mexico are occupied by more than 150,000 lesser long-nosed bats. Although this represents a large number of bats, the relative number of known large roosts is small. Disturbance of these roosts and the food plants associated with the bats could lead to the loss of the roosts. Limited numbers of maternity roosts may be the critical factor in the survival of this species (USFWS 1997).

In spring, adult females, most of which are pregnant, arrive in southwestern Arizona, where they gather into maternity colonies. Roosts are typically at low elevations near concentrations of flowering columnar cacti. Females give birth to a single young. After the young are weaned in July and August, the colonies disperse. Some females and young move to higher elevations (e.g., more than 6,000 feet [1828.8 m] above sea level), primarily in the southeastern parts of Arizona near concentrations of blooming paniculate agaves (reviewed by Cockrum 1991). Actual dates of these seasonal movements by lesser long-nosed bats are rather variable from one year to the next (Cockrum and Petryszyn 1991, Fleming et al. 1993).

Adult males typically occupy separate roosts, forming bachelor colonies. Males are known mostly from the Chiricahua Mountains, but also occur with adult females and young of the year at maternity sites (Cockrum 1991).

Availability of suitable day roosts and suitable concentrations of food plants are the two resources that are believed to be crucial for the lesser long-nosed bat (USFWS 1997). These two factors likely determine suitable habitat within the United States. The factors influencing suitability of roost sites have not yet been identified. The species exhibits sensitivity to human disturbance. A single brief visit to an occupied roost can be sufficient to cause a high proportion of lesser long-nosed bats to temporarily abandon the roost and move to another. It is possible that most of the disturbed bats return to their preferred roost in a few days. However, this sensitivity also suggests that the presence of an alternate roost may be critical when distur-

bance does occur. Interspecific interactions with other bat species may also influence lesser long-nosed bat roost requirements (USFWS 1997).

The species' Recovery Plan specifies that lesser long-nosed bats forage over wide areas and that large roosting colonies require extensive stands of cacti or agave for food (USFWS 1997). Therefore, destruction of food plants many miles from roost sites could have a negative impact on the species. However, in order to protect forage plant species adequately, it is necessary to have an understanding of how the lesser long-nosed bat is using these resources, including assessment of: (1) economical flight distances; (2) suitable distribution of forage plants around the roost sites and along migratory paths; and (3) landscape features of suitable foraging habitat, including forage plant densities, spatial relations between forage areas, and timing of food availability (USFWS 1997).

Biology of Migration

Indiana Bat

Females emerge from the hibernacula before males, generally in late March or early April (Hobson and Holland 1995, Humphrey 1978). For a time, bats remain in the vicinity of their hibernacula, roosting in trees and foraging to regain weight lost during hibernation and to prepare for the stress of migration. This important phase, called staging, occurs from approximately mid-April through early May. In Missouri, one female bat traveled a maximum distance of 6.4 miles (10.3 km) from her roost cave to foraging area, but the maximum distances for the other 5 radio-tagged male and female bats ranged from 1.2 to 2.5 miles (1.9 to 4.1 km) (Rommé et al. 2002). Disturbances during staging could impact bat fitness more than disturbances at other times, since bats are recovering from one stressful period (hibernation) and preparing for a second stressor (migration).

Most hibernating populations have dispersed by early May, migrating as far as 310 miles (500 km) to their summer habitats (Kurta and Murray 2002). Some males spend the summer near their hibernacula (LaVal and LaVal 1980), whereas others migrate out of the area. In Kentucky, MacGregor (J. MacGregor, Endangered Species Biologist, Daniel Boone National Forest, Kentucky, professional communication, December 1998 [hereafter referred to as MacGregor December 1998], as reported in McKenzie 1999) reported that the maximum distance males moved from their hibernaculum in the summer was about 2.6 miles (4.2 km). Sparse band recovery records, all from the Midwest, indicate that females and some males primarily migrate north in the spring upon emergence from their hibernacula (Hall 1962, Barbour and Davis 1969, Kurta 1980, LaVal and LaVal 1980), but there is evidence

of movement in other directions. Although it appears likely that the majority of individuals migrate north, the limited amount of data available on migration and the recent discoveries of reproductive activity further south than previously suspected, suggest interpretation of existing migration data should be cautious.

Spring roosting choices are not a valid basis for describing habitat since post-emergence movement is mostly directional (i.e., the bats are moving toward their summer habitat) and brief. For example, females dispersing from a Kentucky hibernaculum moved 4 to 10 miles (6.4 to 16.1 km) within 10 days (MacGregor December 1998, as reported in McKenzie 1999). Similar distances were reported in Virginia by Hobson and Holland (1995) and in Missouri by 3D/Environmental (1996a). Spring roosting requirements are likely similar to summer roosting habitat requirements. However, because the bats use some areas only briefly as they move towards their summer habitat, these requirements may be less specific.

Gray Bat

All gray bats migrate seasonally between cold winter caves and warm summer caves. Females emerge from hibernation in late March or early April, becoming pregnant soon thereafter. Juveniles emerge next, followed by adult males. Most individuals have left the hibernacula by mid-May (Tuttle 1976b). During both autumn and spring migration, gray bats may roost temporarily in caves, referred to as transitional caves, which may not otherwise be used. Individuals or groups of gray bats may inhabit transitional caves for brief periods in March through April, and September through October before moving to hibernacula or summer roosts (Tuttle 1976b).

The distance traveled by individual colonies varies depending on geographic location; some migration distances range from several miles (kilometers) to up to 326 miles (525 km) (Clawson et al.1992, Tuttle 1976b). Migration may be hazardous, especially in spring when fat reserves and food supplies are low. Consequently, adult mortality is especially high in late March and in April (Tuttle and Stevenson 1977).

Fall migration occurs in the same order as spring migration. Adult females leave summer habitat in early September; juveniles and adult males depart last, usually by mid-October (Tuttle 1976b).

Hawaiian Hoary Bat

Kramer (1971) suggested that the Hawaiian hoary bat might undergo limited seasonal inter-island migration. In contrast, Jacobs (1994) suggested that seasonal

variation in Hawaiian Hoary bat activity occurs over a wide range of elevational and geographic conditions, arguing against inter-island migration. Menard (2001) specifically studied seasonal spatial trends in Hawaiian hoary bat presence and absence to evaluate whether the species appears to migrate between different altitudes. She found that bats do appear to migrate from high elevations to low elevations in the pregnancy and lactation period (April through July), from low elevations to high elevations during the pre-pregnancy period (Jan through March), and exhibit a "partial upslope migration" in the post-lactation period (changes seen during October; Menard 2001). Menard hypothesizes that this migration could be undertaken only by males.

Lesser Long-nosed Bat

The lesser long-nosed bat is migratory and is still found throughout its historic range. The species resides in the United States only during the summer months, from April until October at the latest. Its range extends from southern Arizona and extreme southwestern New Mexico, through western Mexico, and south to El Salvador (USFWS 1997). In southern Arizona, lesser long-nosed bat roosts have been found from the Picacho Mountains (Pinal County) southwest to the Agua Dulce Mountains (Pima County), southeast to the Chiricahua Mountains (Cochise County) and south to the international border. Individuals have also been observed from the vicinity of the Pinaleño Mountains (Graham County) and as far north as Phoenix and Glendale (Maricopa County) (Arizona Game and Fish Department 2003). This bat is also known from far southwestern New Mexico in the Animas and Peloncillo Mountains (Hidalgo County; USFWS 1997).

Biology of Foraging

Indiana Bat

Indiana bats feed strictly on flying insects, with prey items reflecting the environment in which they forage (most often terrestrial insects). Diet varies seasonally and differs with age, sex, and reproductive status (Belwood 1979, Lee 1993). Reproductively active females and juveniles exhibit the greatest dietary diversity, likely because of increased energy needs. Limited evidence suggests reproductively active females may consume more aquatic insects than males or juveniles (e.g., Lee 1993).

Moths (Lepidoptera) are major prey items (Belwood 1979; Brack and LaVal 1985; Lee 1993), but caddis flies (Trichoptera) and flies (Diptera) are also documented as major food items (Kurta and Whitaker 1998). Mosquito and midge species that

form large mating aggregations over water appear to be seasonally important food items (Belwood 1979). Male Indiana bats summering near hibernacula feed primarily on moths and beetles. Other food items include bees, wasps, and flying ants (Hymenoptera), beetles (Coleoptera), stone flies (Plecoptera), leafhoppers and treehoppers (Homoptera), lacewings (Neuroptera), and true bugs (Hemiptera) (Whitaker 1972, Belwood 1979).

Indiana bats require open water for drinking. Streams, small ponds, wetlands, and even road ruts serve as important sources of drinking water during summer months. Upland water sources appear to be important for all bat species, including Indiana bats. The maximum travel distance reported for Indiana bats is about 2.5 miles (4 km). Roosting sites more than 2.5 mi (4 km) from water were assumed to be unsuitable (Rommé et al. 1995).

Indiana bats forage in and around the tree canopy of floodplain, riparian, and upland forests, forest edges, and solitary trees in clearings (Belwood 1979, Cope et al. 1974, Humphrey et al. 1977, Clark et al. 1987, Gardner et al. 1991b). Within floodplain forests where Indiana bats forage, canopy closures range from 30 to 100 percent (Gardner et al. 1991b). Cope et al. (1978) characterized woody vegetation within a width of at least 30 yards (27 m) on both sides of a stream as excellent foraging habitat. Streams, associated floodplain forests, and impounded bodies of water (e.g., wetlands, reservoirs) are preferred foraging habitats for pregnant and lactating Indiana bats (Gardner et al. 1991b). Indiana bats also forage within the canopy of upland forests, over clearings with early successional vegetation, along the borders of croplands, along wooded fencerows, and over farm ponds in pastures (Clark et al. 1987, Gardner et al. 1991b).

Indiana bat maternity colony foraging areas have been found to range from a linear strip of creek vegetation 5 miles (0.8 km) in length (Belwood 1979, Cope et al. 1974, Humphrey et al. 1977) to areas greater than 10 square miles (26 square km). During the relatively short timeframes that they can be radio-tracked, Indiana bats often return nightly to specific foraging areas (Gardner et al. 1991b). Indiana bats usually forage and fly within an air space from 6 to 100 feet (1.8 to 30.5 m) above ground level (Humphrey et al. 1977). Most Indiana bats caught in mist nets are captured over streams and other flyways at heights greater than 6 ft (1.8 m) (Gardner et al. 1989).

During summer, male Indiana bats that remained near their Missouri hibernacula flew cross-country or upstream toward narrower, more densely wooded riparian areas during nightly foraging bouts, perhaps due to interspecific competition with gray bats. Some male bats also foraged at the edges of small flood-plain pastures, within dense forests, and on hillsides and ridgetops; maximum reported distance

was 1.2 mi (LaVal et al. 1976, LaVal et al. 1977, LaVal and LaVal 1980). In Kentucky, MacGregor (MacGregor December 1998, as reported in McKenzie 1999) reported that the maximum distance males moved from their hibernaculum in the summer was about 2.6 mi. In the fall, male Indiana bats tend to roost and forage in upland and ridgetop forests, but might also forage in valley and riparian forests (Kiser and Elliott 1996); movements of 1.8 to 4.2 mi have been reported in Missouri and Kentucky (3D/Environmental 1996a; MacGregor December 1998, as reported in McKenzie 1999).

Although the studies of foraging behavior mentioned above provide insights about habitat use, none compared the use of habitats relative to their availability. In a study of summer habitat use Menzel et al. (2005) attempted to elucidate the relative importance of various habitat types for Indiana bat by comparing use versus availability. Based on a telemetry study in the core of the species' range they were able to quantitatively confirm the observations of many earlier researchers regarding the Indiana bat's preference for forested and riparian areas (Menzel et al. 2005). Comparisons of used versus available habitat also confirmed the importance of linear landscape features such as riparian corridors and roads as either travel corridors or foraging habitat. Menzel et al. (2005) also showed that agricultural areas were avoided, whereas grasslands were neither selected, nor avoided.

Gray Bat

Gray bats feed almost exclusively over water. Maternity caves are usually located within 0.6 miles (1 km), and rarely more than 2.5 miles (4 km), from rivers or reservoirs over which the bats feed. A colony's home range may include up to 40 miles (64 km) of river or reservoir shore-line (USFWS 1982). A variety of aquatic insects are consumed, but the gray bat appears to prefer adult mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) (LaVal et al. 1977). In all, at least 55 families comprising 15 orders of insects are consumed by gray bats (Clawson 1984, Best et al. 1997). These same two studies found conflicting results regarding the selectivity of gray bat prey choice. Clawson (1984) found that dietary components were strongly correlated with prey abundance, whereas Best et al. (1997) found that gray bats were highly selective of prey, especially for the three groups most often consumed: moths, flies, and beetles.

During peak insect abundance in early evening, many gray bats feed in slowly traveling groups. When insect numbers drop, 1.5 to 2 hours after sundown, gray bats become territorial (USFWS 1982). Depending upon prey abundance, foraging territories may be occupied by from 1 to 15 or more bats. Territories seem to be controlled by reproductive females and are located in the same places and used by the same individual bats from one year to the next (Tuttle and Stevenson, 1978).

Gray bats may fly great distances during nightly foraging trips (USFWS 1982). Tuttle (1976b) indicated gray bats regularly made trips of 9 to 21 miles (14.5 to 33.8 km) in a single night. In Tennessee, gray bat foraging territories were identified up to 12 miles (19.3 km) from the roost cave. In Missouri, gray bats were observed foraging as far as 12 miles (19.3 km) from their roost cave, and other individuals traveled approximately 15 miles (24 km) to reach a foraging area over a large lake (LaVal and LaVal 1980). In Alabama, gray bats foraged 3 to 13 miles (4.8 to 20.8 km) from the roost cave (Goebel 1996).

Newly volant young gray bats often feed and take shelter in forest surrounding cave entrances. Also, whenever possible, gray bats of all ages fly in the protection of forest canopy between caves and feeding areas. Such behavior is believed to provide increased protection from predators such as owls. Forested areas surrounding caves and between caves and over-water feeding habitat clearly are advantageous to gray bat survival (Tuttle 1979). Additionally, gray bat feeding areas have not been found along sections of river or reservoir where adjacent forest has been cleared (LaVal et al. 1977; Tuttle and Stevenson 1977).

Hawaiian Hoary Bat

One study found a preference in the Hawaiian hoary bat for moths (Belwood and Fullard (1984). However, Barclay (1985) and Whitaker and Tomich (1983) found no strong selection for moths in a study on Hawaii. Jacobs (1993b) suggested that the Hawaiian hoary bat might have a more diverse diet than the North American hoary bat, possibly due to morphological differences.

Lesser Long-nosed Bat

Lesser long-nosed bats appear to be opportunistic foragers and efficient fliers, capable of flight speeds up to 14 miles (22.5 km) per hour (Sahley et al. 1993), and often foraging in flocks. The lesser long-nosed bat is known to fly long distances from roost sites to foraging sites. One-way flights from maternity colonies to flowering columnar cacti have been documented in Arizona at distances of 15 miles (24 km), and in Mexico at distances of 25 and 38 miles (40 and 60 km) (Dalton et al. 1994; V. Dalton, Tucson, professional communication, 1997; Y. Petryszyn, University of Arizona, professional communication, 1997). A substantial portion of the lesser long-nosed bats at the Pinacate Cave maternity colony in Sonora, fly 25 to 31 miles (40 to 49.6 km) each night to foraging areas in Organ Pipe Cactus National Monument (USFWS 1997). Horner et al. (1990) found that lesser long-nosed bats commuted 30 to 36 miles (48 to 57.6 km) round trip between an island maternity roost and the mainland in Sonora. The authors suggested these bats regularly flew at least 50 to 62.5 miles (80 to 100 km) each night. Lesser long-nosed bats have also been ob-

served feeding at hummingbird feeders many miles from the closest potential roost site (Petryszyn 1997).

Lesser long-nosed bats have very specific food requirements. The lesser long-nosed bat consumes nectar and pollen of paniculate agave flowers and the nectar, pollen, and fruit produced by a variety of columnar cacti. In Arizona, four species of agave and two cacti are the main food plants (Hayward and Cockrum 1971, Wilson 1985). The agaves include Palmer's agave (*Agave palmeri*), Parry's agave (*A. parryi*), desert agave (*A. deserti*), and amole (*A. schotti*). Amole is considered to be an incidental food source. The cacti include saguaro and organ pipe cactus (USFWS 1997).

Nectar of these cacti and agave flowers are high-energy foods. Concentrations of food resources appear to be patchily distributed on the landscape and the nectar of each plant species is only seasonally available, driving intraregional, seasonal movements of the bat. Cacti flowers and fruit are available during the spring and early summer. Blooming agaves are available through the summer, primarily from July through early October, though Parry's agave blooms earlier. Columnar cacti occur in lower elevation areas of the Sonoran Desert region, and paniculate agaves are found primarily in higher elevation desert scrub areas, desert grasslands and shrublands, and into the mountains (USFWS 1997).

Special adaptations, including a long muzzle, a long tongue, and hover flight capabilities, allow the bat to feed on nectar from the flowers of columnar cacti such as the saguaro and organ pipe cactus, as well as the agaves listed above (Brown 1994). Palmer's agave exhibits many characteristics that indicate they are pollinated by bats, including nocturnal pollen dehiscence and nectar production, light colored and erect flowers, strong floral odor, and high levels of pollen protein with relatively low levels of nectar sugar concentrations (Slauson 2000). Parry's agave demonstrates many (although not all) of these same morphological features (Gentry 1982). Slauson (2000) demonstrated that there was a mutualistic relationship between Palmer's agave and the lesser long-nosed bat, although this relationship was asymmetric in that the bat is quite dependent on the agave for food during a certain period, whereas the agave has other pollinator options. Considerable evidence exists to suggest a dependence of *Leptonycteris* spp. on certain agaves and cacti (e.g., Stoner et al. 2003). Activities that adversely affect the density and productivity of columnar cacti and paniculate agaves may adversely affect populations of lesser long-nosed bats (Abouhalder 1992, USFWS 1997).

3 Species' Distributions Near Military Installations

Indiana Bat

In a summary of threatened and endangered species presence on Army installations, Rubinoff et al. (2003) report that the Indiana bat occurs on eight Army installations and occurs in habitat contiguous with three other installations. However the data used in their summary do not include all Army installations or sites where Army training may occur. An alternative assessment, based on county-level distribution data from the species' draft revised recovery plan (USFWS 1999a), suggests the species may occur on as many as 59 military (DoD) installations (Figures 5 and 6, and Table 1).

In addition, caution must be applied when interpreting mist net data for species presence and absence. Capture of endangered bats certainly establishes presence of the species, but lack of capture does not establish absence. A recent example from the Mark Twain National Forest in Missouri illustrates this. In late July 2004, biologists tracked a pregnant bat to a large maternity colony on forest lands. "We'd been doing surveys for six or seven years, and we'd not caught but a couple of Indiana bats," said Jody Eberly, a biologist with the Mark Twain National Forest. "This is the first time we've actually found Indiana bat roost trees on the forest, so we're pretty excited" (*Daily American Republic*, 2004). Thus, a larger geographic perspective, as provided here, is warranted. Consideration of off-site, nearby bat survey results, cave surveys, and habitat assessment can provide a more realistic indication of whether endangered bats are likely to occur, and someday be documented, on Army installations.

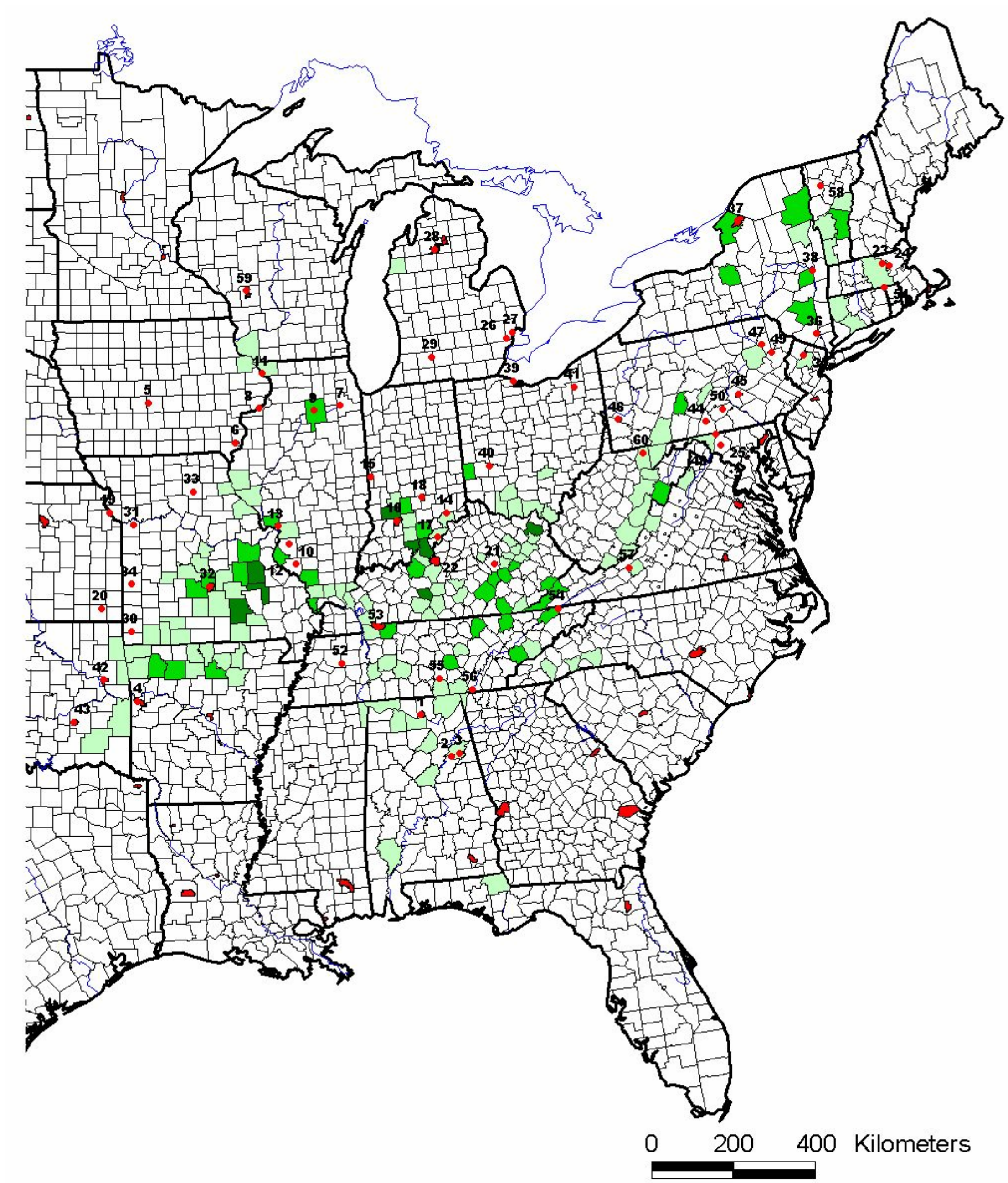

Figure 5. Counties where Indiana bat hibernacula are known to occur (green), relative to the locations of military installations (red).

Counties where Priority I, II, III hibernacula are known to occur are shown in dark, medium and light green, respectively. Numbers correspond with the installation ID listed in Table 1.

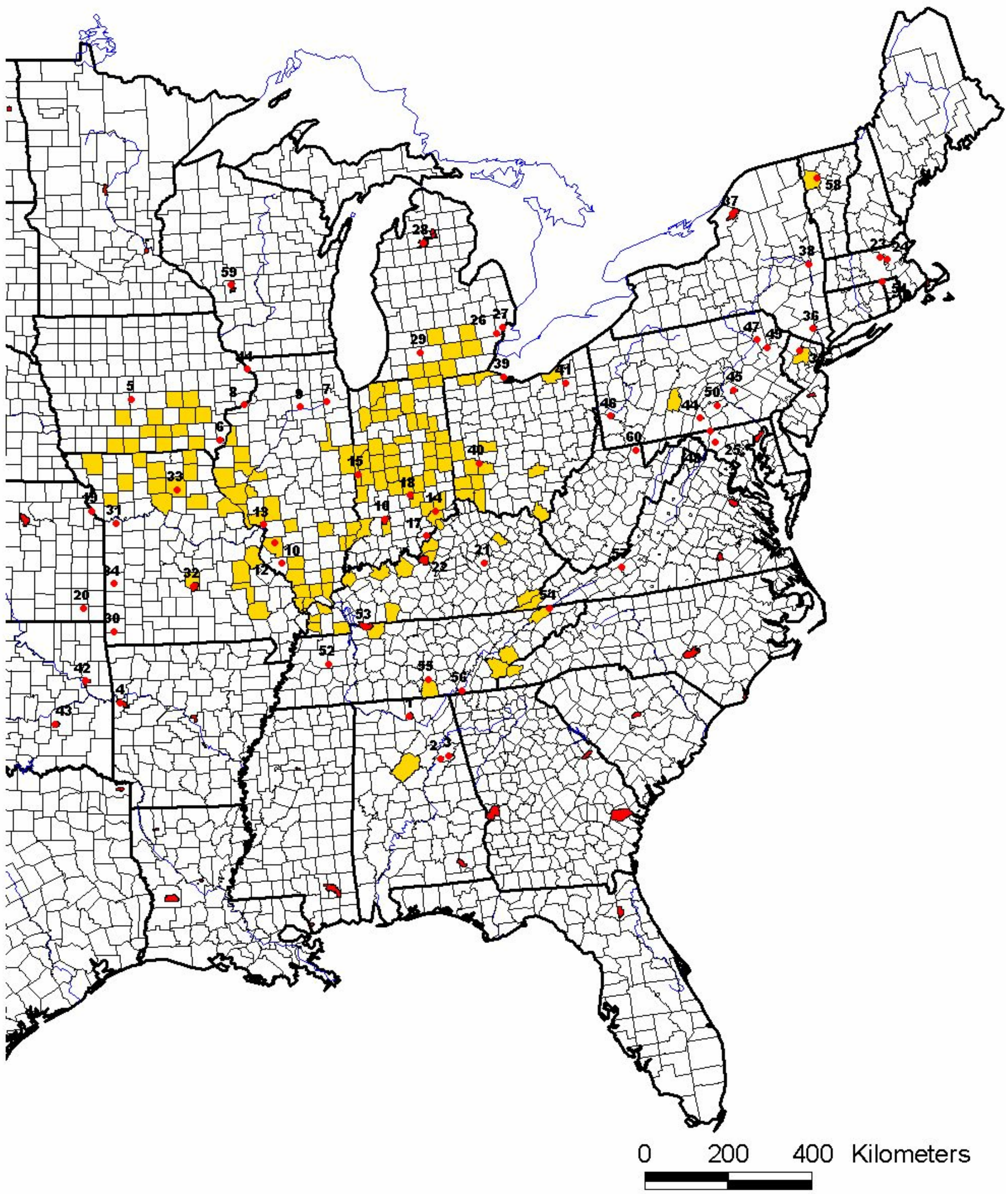

Figure 6. Counties where pregnant or lactating Indiana bats have been observed (yellow), relative to the locations of military installations (red).
Numbers correspond with the installation ID listed in Table 1.

Table 1. Known or likely occurrence of Indiana and gray bats on military installations within the species' geographic ranges. County-level distribution data are mostly from species recovery plans (USFWS 1982, USFWS 1999a)

			Indiana bat			Gray bat	
ID	Installation/Base	State	maternity*	males**	hibernacula†	maternity	hibernacula‡
1	Redstone Arsenal	AL	potential	probable	same Co. (P 3)	documented	adjacent Co.
2	Anniston Army Depot	AL	potential	probable	same Co. (P 3)	adjacent Co.	
3	Fort McClellan	AL	potential	probable	same Co. (P 3)	documented	
61	Fort Rucker	AL				adjacent Co.	
4	Fort Chaffee	AR	potential	probable	adjacent Co. (P 3)	same Co.	
62	Pine Bluff Arsenal	AR				adjacent Co.	
5	Camp Dodge	IA	adjacent Co.	potential			
6	Iowa AAP	IA	adjacent Co.	documented			
7	Joliet TA	IL	potential	potential			
11	Savanna AD	IL	potential	potential	same Co. (P 3)		
13	Charles M Price SC	IL	adjacent Co.	probable	same & adjacent Cos. (P 3 & P 2)		
10	Sparta TS	IL	adjacent Co.	probable	adjacent Cos. (P 2)		
12	Scott AFB	IL	documented	probable	adjacent Cos. (P 2 & P3)		
8	Rock Island Arsenal	IL	potential	potential			
9	Marseilles TS	IL	same Co.	probable	same Co. (P 2)		
17	Indiana AAP	IN	adjacent Co.	probable	same Co. (P 3)	documented	
14	Jefferson PG*	IN	documented	documented	same Co. (P 3)		
15	Newport CD	IN	documented	documented			
18	Camp Atterbury TS	IN	documented	documented			
16	Crane NSWC	IN	documented	documented	adjacent Co. (P 1)		
19	Fort Leavenworth	KS	adjacent Co.	potential			
20	Kansas AAP	KS	potential	potential	adjacent Co. (P 3)	adjacent Co.	
21	Blue Grass Army Depot	KY	potential	probable	adjacent Cos. (P 2 & P 3)	same Co.	
22	Fort Knox	KY	same Co.	documented	same Co. (P 3) adjacent Co. (P 1)	documented	same Co.

ID	Installation/Base	State	Indiana bat			Gray bat	
			maternity*	males**	hibernacula†	maternity	hibernacula‡
23	Fort Devens	MA	potential	probable	same Co. (P 3)		
24	Soldier Systems Center	MA	potential	probable	adjacent Co. (P 3)		
25	Fort Detrick	MD	potential	probable	adjacent Co. (P 3)		
29	Fort Custer	MI	adjacent Co.	potential			
27	US Army Garrison Selfridge	MI	potential	potential			
26	Detroit Arsenal	MI	unlikely	unlikely			
28	Camp Grayling	MI	potential	potential			
33	Macon TS	MO	same Co.	potential			
31	Lake City AAP	MO	potential	potential			
30	Camp Crowder	MO	potential	probable	adjacent Cos. (P 3)	adjacent Co.	
32	Fort Leonard Wood	MO	same Co.	documented	same Co. (P 2)	documented	adjacent Co.
34	Camp Clark	MO	potential	potential		adjacent Co.	
35	Picatinny Arsenal	NJ	same Co.	documented	same Co. (P 3)		
36	US Military Academy	NY	potential	documented	adjacent Co. (P 2)		
38	Watervliet Arsenal	NY	potential	probable	adjacent Co. (P 2)		
37	Fort Drum	NY	potential	probable	same Co. (P 2)		
40	Wright Patterson AFB	OH	documented	potential			
41	Ravenna AAP	OH	adjacent Co.	potential			
39	Camp Perry	OH	adjacent Co.	potential			
42	Camp Gruber	OK	potential	probable	adjacent Co. (P 3)	adjacent Co.	
43	McAlester AAP	OK	potential	probable	adjacent Co. (P 3)		
50	Carlisle Barracks	PA	potential	potential			
46	Kelly Support Center	PA	potential	potential			
44	Letterykenny AD	PA	potential	probable	adjacent Co. (P 3)		
49	Tobbyhanna AAP	PA	potential	potential	adjacent Co. (P 3)		
47	Scranton AAP	PA	potential	probable	adjacent Co. (P 3)		

ID	Installation/Base	State	Indiana bat			Gray bat	
			maternity*	males**	hibernacula†	maternity	hibernacula‡
45	Fort Indiantown Gap	PA	potential	potential			
48	Fort Ritchie	PA	potential	probable	same Co. (P 3)		
51	Camp Fogarty	RI	potential	probable	adjacent Co. (P 3)		
55	Tullahoma TS	TN	potential	probable	adjacent Co. (P 3)	adjacent Co.	adjacent Co.
56	Volunteer AAP	TN	potential	probable	adjacent Co. (P 3)	adjacent Co.	adjacent Co.
54	Holston AAP	TN	adjacent Co.	probable	adjacent Co. (P 2)	documented	same Co.
52	Milan Arsenal	TN	potential	potential			
53	Fort Campbell	TN	same Co.	documented	same Co. (P 2)	documented	same Co.
57	Radford AAP	VA	potential	probable	adjacent Co. (P 3)		
58	Camp Ethan Allen	VT	same Co.	probable	adjacent Co. (P 2)		
59	Fort McCoy	WI	potential	potential			
60	Camp Dawson	WV	potential	probable	same Co. (P 3)		

* potential = documented within two counties.

** potential = hibernacula within two counties; probable = hibernacula within same county.

† P 1 = Priority I (one or more record of >30,000 bats since 1960); P 2 = Priority II (one or more record of 500-30,000 bats since 1960; P 3 = Priority III (one or more record of <500 bats since 1960).

‡ Only primary hibernacula (25,000 to 50,000 individuals) were considered.

Gray Bat

In a summary of threatened and endangered species presence on Army installations, Rubinoff et al. (2003) report that the gray bat occurs on seven Army installations and occurs in habitat contiguous with one other installation. However the data used in their summary do not include all Army installations or sites where Army training may occur. Figures 7 and 8, and Table 1 (page 26) present an alternative representation of the species' documented and potential occurrence on military installations, based on county-level distribution information (USFWS 1999a). If suitable aquatic foraging sites or forested travel corridors are present, gray bats could occur on an additional eleven installations.

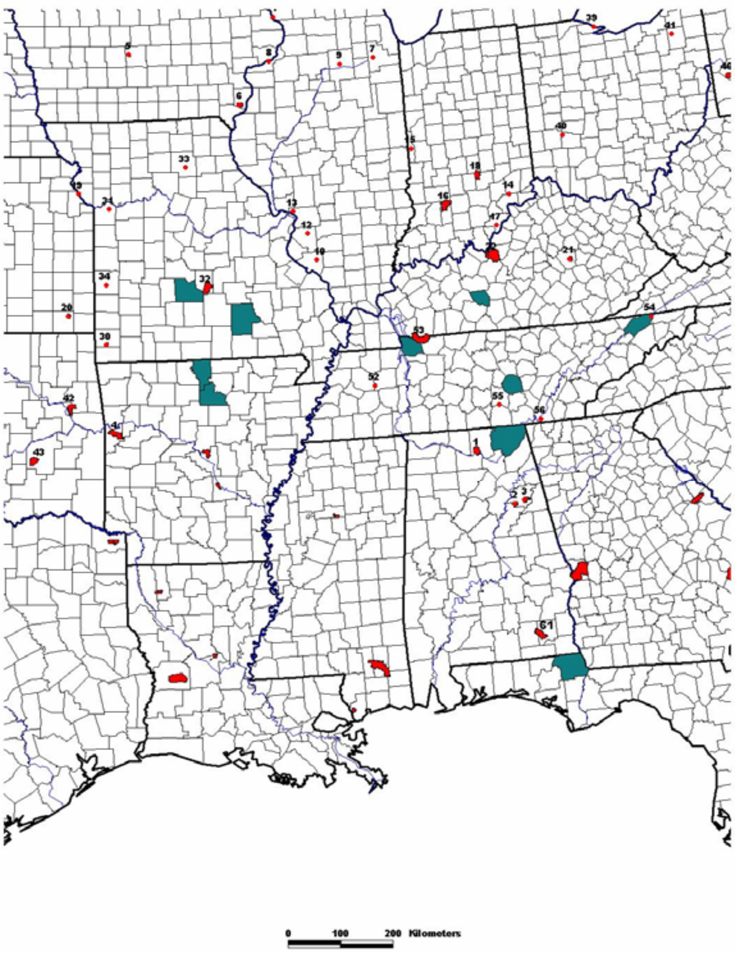

Figure 7. Counties where Priority I (>50,000 individuals), gray bat hibernacula are known to occur (blue), relative to the locations of military installations (red).
Numbers correspond with the installation ID listed in Table 1.

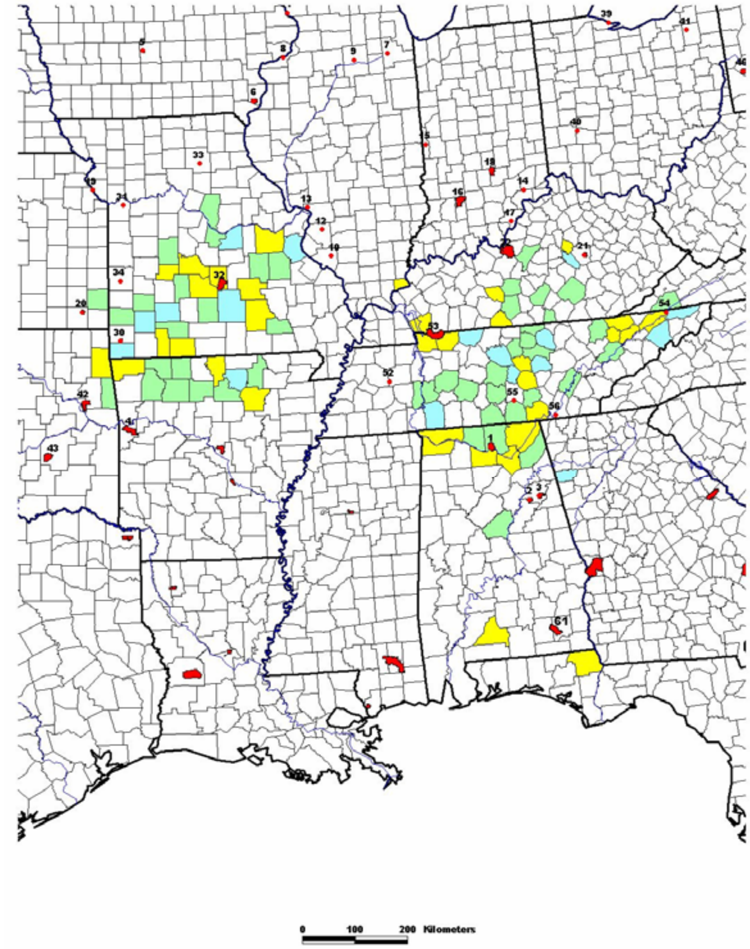

Figure 8. Counties where gray bat maternity caves are known to occur (yellow=Priority I [>50,000 individuals], green=Priority II [25,000-50,000], blue=Priority III [<25,000]), relative to the locations of military installations (red).
Numbers correspond with the installation ID listed in Table 1.

Hawaiian Hoary Bat

In a summary of threatened and endangered species presence on Army installations, Rubinoff et al. (2003) report that the Hawaiian hoary bat occurs on only four installations. However the data used in their summary do not include all Army installations or sites where Army training may occur. An alternative assessment, based on distribution information within the species' recovery plan suggests the species may actually occur on 25 Army and Army National Guard installations (Table 2).

Table 2. Hawaiian hoary bat presence on Army installations and Army National Guard training areas and facilities.

Installation	Hawaiian hoary bat presence*
Keaukaha Military Reservation	documented
Kawailoa TA	documented
Makua Miltary Reservation	documented
Pohakuloa TA	documented
Wahlawa Armory	Potential
Fort Ruger Diamond Head	Potential
Ukumehame Firing Range	Potential
Pu'unene Airstrip	Potential
Kahului Armory	Potential
Kanaio Local Training Area	Potential
Honopou Stream Local Training Area	Potential
Kapaa Armory	Potential
Nonou Local Training Area	Potential
Aahoaka Local Training Area	Potential
Anahola Local Training Area	Potential
Kekaha Firing Range and LTA	Potential
Hanapepe Armory	Potential
Kaunakakai Armory	Potential
Kealakekua Armory	Potential
Keaau Armory	Potential
Hilo Armory	Potential
Honokaa Armory	Potential
Pauuilo LTA	Potential
Puu Pa LTA	Potential
Kilohana LTA	Potential
Schofield Barracks	Potential

* potential = observed in the general area during the past 30 years (from USFWS 1998b).

Lesser Long-nosed Bat

In a summary of threatened and endangered species presence on Army installations, Rubinoff et al. (2003) report that the lesser long-nosed bat occurs only on one installation (Fort Huachuca, AZ). However the data used in their summary do not include all Army installations or sites where Army training may occur. An alternative assessment, based on county-level distribution information from the species' recovery plan suggests the lesser long-nosed bat may also occur on Florence Military Reservation, AZ, and Yuma Proving Ground, AZ (Figure 9).

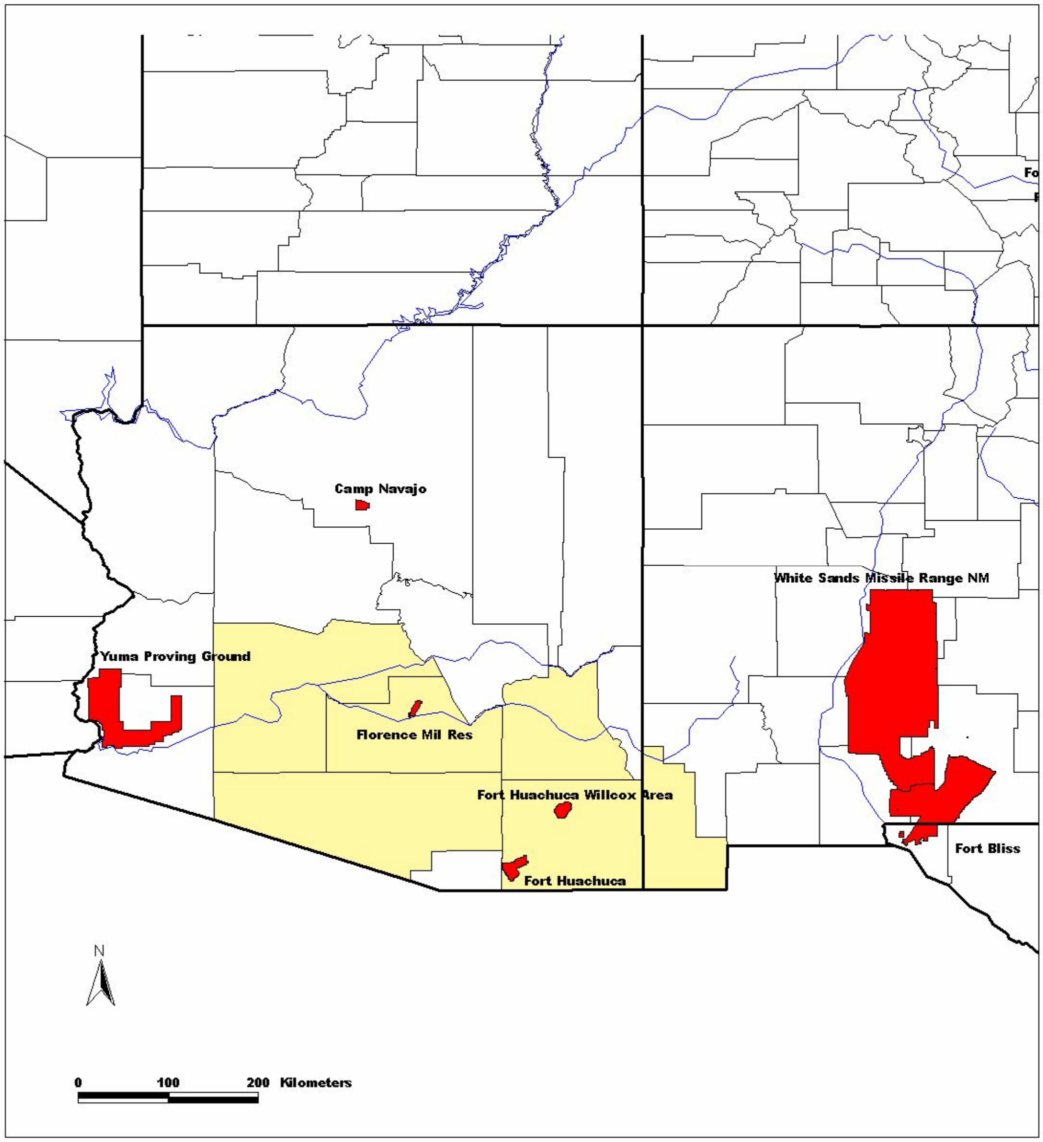

Figure 9. Counties in Arizona and New Mexico where lesser long-nosed bats are known to occur (yellow) and nearby Army and National Guard installations (red).

4 Threats to Species

Indiana Bat

Documented causes of population decline

Several factors were identified in the species recovery plan (USFWS 1999a) that were likely to have contributed to the decline of the Indiana bat throughout its range. In the past, the most significant impacts included human disturbance of hibernating bats and intentional vandalism. Human entry into a hibernaculum during the winter causes hibernating bats to awaken. Each time a bat awakens, it uses a substantial amount of the fat reserves it has accumulated for the winter, possibly as much as 68 days' worth of energy reserves with each arousal (Thomas et al. 1990). Multiple disturbances lead to loss of all stored fat reserves before the hibernation period ends. Bats are then forced to leave the cave too early in the year (i.e., before emergence of insects) to search for food, after which they die of starvation and/or cold stress.

Vandalism is also a serious problem that has resulted in the deliberate destruction of entire bat colonies simply because these animals are often viewed by the public as nuisances or threats to human health (reviewed by USFWS 1999a).

In the past, some hibernacula were rendered unavailable to bats by the installation of solid gates at the cave entrances. Gates can also sometimes alter the airflow within a cave to the extent that metabolic rates of hibernating bats are affected. In some cases, bats again lose their fat reserves prematurely, and die from the indirect effect of gating. In some cases, correction of the gate installation has restored large populations of Indiana bats. In other cases, large population gains did not follow gate improvement (reviewed by USFWS 1999a).

Caves occupied by Indiana bats (and other bat species) occasionally flood or collapse, killing a few to thousands of bats. Gates can sometimes exacerbate this risk if flood debris collects on a gate, breaks the gate, and deluges the cave with water suddenly (reviewed by USFWS 1999a).

Suspected causes of population decline

Microclimatic conditions within hibernacula are critically important for the survival of Indiana bats. Limited data indicates that when Indiana bat colonies roost at temperatures below 35 °F (1.9 °C) or above 47 °F (8.4 °C), the population usually declines; when colonies roost between 37 °F (3.8 °C) and 45 °F (7.3 °C), cave populations tend to grow (Tuttle, and Kennedy 2002). Microclimate changes over time due to alteration of airflow when passages change in size, become blocked, or portions of a cave collapse. Any modification to a cave that alters airflow could have significant consequences (Richter et al. 1993, Tuttle 1998, USFWS 1999a).

Timber harvest, water quality degradation, stream channelization, and other land use activities can in some cases result in destruction or alteration of actual or potential roosting and/or foraging habitat (USFWS 1999a). The forest habitat of the Indiana bat has changed drastically from presettlement conditions throughout its range. In some cases, forest cover has declined. Fire regimes have been suppressed. In other areas, forest cover has become denser. It is unknown exactly how land-cover changes affect the Indiana bat. The age, composition, and size class distributions within forest habitat are factors believed to determine habitat suitability for the Indiana bat. A clearer understanding of the Indiana bat's summer habitat requirements is needed before a science-based assessment of the impact that changes in summer habitat have on populations (USFWS 1999a).

Potential impacts of military training, testing, and natural resources management

Habitat modification

Immediate mortality and long-term loss of roosting trees and roosting habitat are the common concerns during typical military land development actions. For example, when Fort Knox, KY, proposed to reconfigure three entire training ranges and a portion of a fourth range into a qualification training range, the installation proposed to remove approximately 80 acres (32.4 ha) of forested habitat. This habitat was believed to include suitable roosts for the Indiana bat. The resulting Biological Opinion (USFWS 1998a) evaluated the risk of direct mortality if development occurred between March 16 and September 15, the risk of loss of all available suitable roosts in the immediate area, or the loss of suitable roosting habitat by reduction of forest cover to less than 30 percent. In another example, the Biological Opinion for construction of a multipurpose training range on Camp Atterbury, IN (Pruitt 1998) considered the loss of 246.3 acres (99.7 ha) of suitable Indiana bat habitat, including the possibility of loss of foraging habitat, requiring bats to fly farther each night to forage. Similar considerations are evaluated any time conversion of forest is consid-

ered within bat roosting or foraging habitat, whether for military or natural resource purposes.

Due to construction and use of a multipurpose training range on Camp Atterbury, it was suspected that foraging habitat would be degraded by erosion and sedimentation in streams, possibly affecting the production of aquatic insects which comprise a portion of the Indiana bat prey base (Pruitt 1998).

Noise

An extensive chemical and noise-related Ecological Risk Assessment (ERA), was conducted for Fort Leonard Wood, MO (3D/Environmental 1996a). Experimental studies were conducted to specifically address the potential for impacts to Indiana bats from airborne sounds and seismic vibrations generated from specific military training activities associated with ranges near Indiana bat hibernacula. Researchers induced hibernation in ten Indiana bats collected from Pilot Knob Mine, Missouri's largest bat hibernaculum. The bats were caught in active swarming behavior on November 9 and placed into 5 °F (-15 °C) soundproofed chambers, whereupon they began to hibernate. Recorded sounds from four training ranges were played for six experimental animals. The sounds presented to experimental animals represented sound levels on training ranges, not sound levels within natural cave environments. No response in body temperature was recorded. However, by January 11, 8 of the 10 Indiana bats were dead, and the other 2 did not survive the duration of the experiment. It is believed that conditions related to capture of bats that were actively swarming at a late date and placing them directly into hibernation led to their deaths. Following their deaths, four little brown bats (*Myotis lucifugus*) were captured while already hibernating and were placed into hibernation chambers in the laboratory and subjected to the remaining noise treatments. All survived and none displayed any measurable reaction to the recorded sounds of military training. There are concerns with assuming that little brown bats can be used as surrogates for Indiana bats for experiments involving hibernation (3D/Environmental 1996a). However, the experiment was repeated with 28 little brown bats and led to the same results — no measurable response in hibernating little brown bats to recorded training sounds of 65 to 115 decibels (dB) (3D/Environmental 1996b). A Biological Assessment for Camp Atterbury used existing data and site-specific information on noise generation to evaluate the potential for impacts to Indiana bats by loud sounds from military training exercises (Tetra Tech, Inc. 2002). This analysis concluded that noise generated by training activities on a new training range would not adversely affect the bats.

The same research project on Fort Leonard Wood (3D/Environmental 1996a) measured actual sound and seismic vibrations within caves serving as Indiana bat hiber-

nacula. Recording equipment was located as closely as possible to locations of past roost sites within the caves. Low frequency airborne sound, seismic vibrations, audible airborne sound, ultrasound and sound pressure levels were all measured. Neither ultrasound nor seismic vibration was perceptible in either of the two hibernacula. One training range produced an occasional audible sound of barely detectable levels (1 to 2 dB) in one cave. Other than that, no training sounds were recorded above background levels of sound in either cave. The studies did not address impacts to Indiana bats during swarming or spring staging activities, nor did they experimentally assess the potential for damage to the auditory systems of Indiana bats from training sounds (3D/Environmental 1996a).

No studies have specifically quantified hearing sensitivity in Indiana bats, nor compared such data to the sounds created by military activities. Some research on little brown bats has been conducted and may be used to estimate sensitivity in Indiana bats. Shimozawa et al. (1974) established that echolocation sounds and audiograms of little brown bats and gray bats are essentially the same. It is thought that sensitivity to sound correlates to the peak frequency range used during echolocation (Suthers 1970). For little brown bats, the peak frequency has been measured at 45 kHz (Fenton and Bell 1981), with peak sensitivity in little brown bats measured at 40 kHz (Dalland 1965). Indiana bats demonstrated peak echolocation frequency of 50 kHz with a range of 41 to 75 kHz (Fenton and Bell 1981). Such information can be compared to the audio characteristics of various activities to assess potential sensitivity. This approach was used during the biological assessment for ongoing military activities on Fort Leonard Wood, and concluded that Indiana bats may be affected by frequent exposure to certain ranges, at distances of 100 to 500 meters (3D/Environmental 1996a). Current research funded by the Army basic research program will characterize the high frequency properties of relevant blast wave patterns that may pose a risk to endangered bats on military installations. In addition, big brown bats (*Eptesicus fuscus*) will be exposed to different doses of high-pressure shock waves, and auditory brain-stem response (ABR) techniques will be used before and after exposure to measure loss of hearing. This project expects to produce dose-response functions that can be used to predict risk to endangered bats at various distances to heavy artillery blasts (Larry Pater, Acoustician, U.S. Army Engineer Research and Development Center-Construction Engineering Research Laboratory [ERDC-CERL], professional communication, 19 August 2004).

Schmidt and Joermann (1986) discovered that noise of similar frequencies to echolocation calls only slightly impaired the ability of bats to echolocate (through interference). Bats tend to alter the call frequency and the intensity of their own sounds to help discriminate between their own sound and the noise.

Additional work on Fort Leonard Wood used radio telemetry to monitor the foraging behavior of nine Indiana bats. This project demonstrated that for a small sample size of bats (n=5), military training activity and noise on specific ranges did not alter their choice of foraging location, when nights with and without training were compared (3D/Environmental 1996a). In June 2002, a male adult bat was captured on Fort Campbell, KY. This bat was radiotracked and observed foraging and night-roosting in approximately the same location near the Impact Area during three nights when training activities (frequent, low-altitude helicopter flights and artillery firing) occurred, as well as during nights when little or no training occurred. There was no apparent difference in the nightly movements of the Indiana bat on nights when training occurred as compared to nights when no training occurred (BHE Environmental, Inc. 2002b).

Additional work is currently underway by ERDC research labs to assess the potential of high-caliber weapons fire to cause temporary or permanent hearing loss, interference in echolocation, disruption of diurnal thermoregulatory behavior, and avoidance of preferred feeding areas due to nearby weapons noise (David Delaney, Research Biologist, ERDC-CERL, professional communication, 19 August 2004). Field observations and measurements of bat presence and activity in response to real-time training activities provide the primary methodology of this project.

Smokes and obscurants

Research conducted for Fort Leonard Wood (3D/Environmental 1996a) focused on inhalation toxicity for two chemicals: hexachloroethane (HC) and terephthalic acid (TPA). HC and TPA are the major components of many common military obscurant devices. HC is much more toxic than TPA (Montgomery Watson and 3D/International 1998), and use of HC has been eliminated on certain installations to protect endangered bats (e.g., Fort Leonard Wood and Camp Atterbury), thus impacting the military mission to some degree. The Fort Leonard Wood ERA process primarily addressed risk of exposure through geographic contours/zones of contamination risk. In other words, the evaluation focused on whether or not bats would be likely to physically encounter dangerous concentrations of chemicals within their roosts or foraging ranges. It was reported that bats roosting or foraging within 10,000 meters of one HC smoke pot may be affected by inhalation of unsafe concentrations of toxic components of the smoke (3D/Environmental 1996a). The risk for inhalation toxicity from TPA smoke pots is significant within 2,000 meters of use (3D/Environmental 1996a).

An ERA for smoke and obscurant use on Camp Atterbury identified impacts from the HC component of AN-M8 smoke grenades both to roosting and foraging bats (Montgomery Watson and 3D/International 1998). In response, Camp Atterbury

committed to not using AN-M8 grenades. The same re-search also indicated that TPA found in M18 colored smoke grenades may cause acute toxicological effects to bats roosting within 36 meters of a deployed grenade within the first minute of smoke release (Montgomery Watson and 3D/International 1998). Based on this, restrictions are now in place on Camp Atterbury regarding these materials (Pruitt 1998).

Smoking operations are conducted during daylight hours, when bats are roosting, and the smoke cloud disperses rapidly in most cases (within a few minutes to 2 hours of cessation). Therefore, it is unlikely that endangered bats would fly through smoke from fog oil or other obscurants (Getz et al. 1996). Direct dermal absorption by bats has not been established, but quantification would require invasive research techniques, including sacrifice of study animals, and thus is not recommended at this time when the degree of contact with aerosolized or deposited oils is not yet established (Getz et al.1996).

Fog oil droplets potentially could temporarily accumulate on the surface of roosting structures and on vegetation. Droplets also could accumulate on the bodies of insects that are then consumed by bats. The likelihood of foliar deposition decreases with decreasing oil droplet size. For the purposes of intentional insecticidal use of petroleum-based aerosolized oils, it has long been known that droplets sizes between 30 and 80 microns in diameter are most effective (Potts 1959). In comparison, there is little deposition of droplets less than 20 microns in diameter (Potts 1946, Reist 1993, Nicholson 1995). In field tests of fog oil smoke generators, the diameter of oil droplets ranges from 0.9 to 3 microns near the generator (Young et al. 1989, Dunn et al. 1998). A field value of 0.7 microns was reported for oil droplets a distance of 25 m from the generator (Liljegren et al. 1989). However, simulated field generations of fog oil smoke in the laboratory have shown that environmental factors, especially wind speed and canopy structure (the amount of surface areas and protrusions on vegetation) can increase foliar deposition of the oil droplets (Cataldo et al.1989). A recent Strategic Environmental Research and Development Program (SERDP)-funded project measured deposition of colored signal smoke, fog oil, and a combination of fog oil and graphite at various distances from release point under field conditions (Cropek 2003). Preliminary results indicated that fog oil deposition can be measured from water samples at distances of up to 50 meters from the release point, but no deposition was detected at greater distances, following up to 18 minutes of fogging exposure. Due to a lack of controlled conditions, the significance of this finding is unclear. Researchers found evidence that the heavier components of fog oil are more likely to be deposited rather than volatilized, and these heavier components are likely to be more harmful to biotic organisms (Cropek 2003). At a research in-progress review meeting in April 2003, researchers at Pacific Northwest National Laboratory presented information on research conducted to measure the

toxicity of fog oil droplets on several insect taxa of importance to endangered birds and bats (Strenge and Driver 2003). Preliminary results showed that under some controlled and replicated laboratory conditions, exposure to fog oil resulted in reduced mosquito larval survival, increased mortality to adult ants, decreased survival and activity of adult moths, as well as decreased adult emergence from the last larval instar in the same moth species. In addition, Cropek (2003) exposed seven different aquatic fauna to colored signal smoke, fog oil, and a fog oil-graphite combination. Effects of exposure to these compounds were performed at 9 locations from the release point, ranging in distance from 1 m to 800 meters. Organisms were monitored for effects for 48 hours. Preliminary results did not reveal any significant mortality due to exposure to colored signal smoke or to a combination of fog oil and graphite. However, after both a 3-minute exposure and an 18-minute exposure to fog oil, significantly higher mortality was measured in daphnids as compared to control organisms (Cropek 2003). Field conditions during these preliminary exposure experiments were highly variable, and reduce the strength of any conclusions.

One component of fog oil smoke is a group of chemicals called polycyclic aromatic hydrocarbons (PAHs). Certain metabolites of these compounds are considered “the ultimate carcinogens” (Schmidt et al. 2002). PAHs were detected in the tissues of all 46 bats collected from 16 sites on Fort Leonard Wood, Missouri, and from 3 reference sites in the Mark Twain National Forest, Missouri. Bats in Missouri are exposed to PAHs, they metabolize and probably excrete PAHs, and also likely store the compounds in their tissues. However, there was no evidence from this study that fog oil use on Fort Leonard Wood increased risk from these chemicals. Bats collected from the National Forest had higher levels of PAHs in their tissues when compared to bats from Fort Leonard Wood (Schmidt et al. 2002).

Pesticides

Organochlorine pesticide residues in the environment have killed gray bats and other species of insectivorous bats in the United States, even though these compounds have been banned for most uses since the 1970’s (O’Shea and Clark 2002). For example, in 1983, dead gray bats were found in Missouri with concentrations of heptachlor epoxide of 2.6 ug/g to 6 ug/g (Clawson and Clark 1989). Two gray bats found dead in 1991 were presumed to be killed by heptachlor epoxide, chlordane, and DDE (Clawson 1991). Lethal quantities of dieldrin were found in bats in both Indiana and Missouri prior to the mid-1980’s; bats collected in 1996 and 1997 revealed a high incidence of dieldrin exposure, but a low probability of lethal levels (O’Shea and Clark 2002). Since organochlorine-based pesticides are no longer used, they appear to be decreasing in the environment and in the tissues of sampled bats (O’Shea and Clark 2002, Schmidt et al. 2002), with the possible exception of DDE, a metabolite of DDT (O’Shea and Clark 2002).

The USFWS and bat biologists have voiced concern regarding the threat of modern pesticides as well. Two classes of compounds, organophosphates and carbamates, are highly toxic cholinesterase inhibitors, but are not fat soluble. This means that these compounds may kill bats from acute exposure, but are not expected to bioaccumulate in tissues. Schmidt et al. (2002) reported no measurable residue of either Malathion or chlorpyrifos (Dursban) within the tissues of 95 bats collected at 19 sites in Missouri, including 16 on Fort Leonard Wood. O'Shea and Clark (2002) review available data from testing bat tissues and guano for the presence of organophosphate and carbamate compounds. Typically, no evidence of these toxins is found in tissues or guano collected in the field, although at least two studies recorded a single individual bat with severe depletion of cholinesterase, indicating possible fatal acute exposure (McFarland 1998; Clark et al. 1996). There are significant difficulties with detecting inhibition of cholinesterase from field samples. Only one major die-off in bats has been attributed to exposure of pesticides that inhibit cholinesterase: Mexican free-tailed bats (*Tadarida brasiliensis*) in 1968 (Clark 1986).

Grue et al. (1997) reviewed a variety of sublethal effects of these modern compounds on thermoregulation, food consumption, and reproductive behavior in mammals. High concentrations of pesticides near and within roost cavities may cause mortality and illness to single males or females, or to maternity colonies of Indiana bats. Clark (1986) and Clark and Rattner (1987) studied the lethal dose of organophosphate compounds in the laboratory, comparing sensitivity between laboratory mice and little brown and big brown bats. While bats survived higher doses of toxins compared to mice, surviving bats demonstrated severe sublethal impacts that would likely lead to mortality in the natural environment. For example, up to 30 percent of bats surviving exposure to acephate suffered from significant loss of coordination and the inability to right their bodies when placed on their backs. In comparison, surviving mice appeared normal in neurological function (Clark and Rattner 1987). There is evidence that dermal exposure leads to the same neurological impacts as ingestion (Clark 1986). In addition, older studies, demonstrating high LD-50 measures in bats, may be inaccurate. McFarland and Drobney (1998) found an LD-50 value for field-grade permethrin in little brown bats to be lower than that reported on the product's Material Safety Data Sheet. Pyrethroid pesticides, such as permethrin, are increasing in use, and there is very little study of their effects on bats. They are neurotoxins, similar in action to DDT, and may persist in the environment for a long time period if they are used in chlorinated form (O'Shea and Clark 2002).

It also is possible that repeated exposure to these pesticides would have cumulative impacts even though the chemicals are not accumulating in tissues (Hoffman et al. 1995). It is also important to consider the possibility of indirect impacts to the Indi-

ana bat through alteration of insect population levels and diversity in the treatment area.

A Biological Assessment (BA) at Fort Leonard Wood determined that bats within 2,000 meters of Malathion release points would be susceptible to toxic effects (3D/Environmental 1996a). The BA process considered Dursban as well, but since this chemical is not applied in an aerosol form, it was not considered toxic through inhalation pathways (3D/Environmental 1996a). The BA did not identify risks for dermal or ingestion exposure, since adequate data are not available. However, it is believed that bats could ingest toxins from contamination of water sources, or possibly from prey. It was reported that HC, Malathion, and Dursban are all somewhat fat soluble, and could theoretically accumulate in the milk of lactating females bats, indirectly affecting young (3D/Environmental 1996a).

The Biological Assessment also assumed that insect prey populations are large enough that food resources for endangered bats would not be limited through the use of chemicals, even at concentrations that are toxic to insects (3D/Environmental 1996a). This statement is not supported by any data or discussion, and its validity merits further evaluation.

Pesticide use is an important component of natural resources management at Newport Chemical Depot, IN. Agricultural lessees who engage in row crop farming on the Depot's land use pesticides that were the topic of a Biological Opinion (McWilliams-Munson 1999) regarding potential impacts on the Indiana Bat. In some cases, leased tracts of land exist in close proximity to known Indiana bat maternity roosts. Thus, the management of herbicide use and pesticide use became an important issue for the Depot and the USFWS. The USFWS clearly believed, based on literature review and discussions with species experts, that aerial spraying of chemicals near bat colonies and the ground application of chemicals without buffer zones near bat colonies were likely to adversely affect the species (McWilliams-Munson 1999).

Additionally, the food supply of the Indiana bat may be reduced by the use of agricultural pesticides. A biological evaluation submitted by Newport Chemical Depot to the USFWS on 25 November 1998 included a literature review that failed to find any scientific literature related to herbicide impacts on bats and their insect food source. However, studies have been conducted on the food base of insectivorous birds. Two studies revealed that herbicide drift and overspray reduced the plant base for insects at the edges of crop fields, and thus, reduced the insect prey base for two species of birds. The alteration of food supply was cited as the primary cause of population declines in the bird populations (Stinson and Bromley 1991). It is likely

that herbicides have an important impact on the insect populations that support Indiana bat populations.

Gray Bat

Documented causes of population decline

The restricted habitat requirements of the gray bat render the species highly vulnerable to impacts from human activities such as cave exploration, cave commercialization, and intentional vandalism. The 80 to 88 percent decline in gray bat populations from the early 1960's until the late 1970's (USFWS 1982) is mainly attributed to human disturbance (reviewed in Mitchell 1998). Often, people who disturb gray bat colonies during casual summertime recreation believe that the bats move to other caves when they abandon their roost. However, this is an erroneous assumption when applied to gray bats. Gray bat colonies are extremely loyal to single caves or groups of caves (Tuttle 1976b) and have limited ability to move to different caves, especially for the rearing of young (Tuttle 1979). Disturbance at maternity caves is most harmful from late May through mid-July, when nonvolant young are present in the roosts; thousands may die from a single disturbance episode (USFWS 1982). Human disturbance at hibernacula from mid-August until April can reduce energy reserves and cause high levels of mortality. Unpublished data from Tuttle indicated that each arousal episode may expend as much energy as a hibernating bats normally uses over a period of 10 to 30 days of undisturbed hibernation (reported in USFWS 1982).

Environmental impacts from deforestation, chemical contaminants, and impoundment of waterways have also contributed to population declines in the gray bat. These impacts are not understood as well as impacts related to human disturbance. Forest cover is important to bats near their cave entrances and along routes to foraging areas. Bats fly between their roosts and their feeding areas in the forest canopy, gaining significant protection from predators. Gray bats have been observed to fly out of their way to seek the safety of forest cover (Tuttle 1979). Young bats are especially dependent on the protection of forest cover, and forage close to the maternity cave for several nights before venturing further away.

The effects of agricultural pesticides in the decline of gray bat populations have been reviewed by Mitchell (1998). Clark et al. (1978) reported mortality and probably population decline resulting from routine insecticide use; unusually high levels of residues from insecticides were found in guano samples from bat caves (Tuttle 1976a). Organochlorine pesticide residues in the environment have killed gray bats and other species of insectivorous bats in the United States, even though these com-

pounds have been banned for most uses since the 1970's (O'Shea and Clark 2002). For example, in 1983, dead gray bats were found in Missouri with concentrations of heptachlor epoxide of 2.6 ug/g to 6 ug/g (Clawson and Clark 1989). Two gray bats found dead in 1991 were presumed to be killed by heptachlor epoxide, chlordane, and DDE (Clawson 1991). Mayflies, a significant dietary item for gray bats, are sensitive to aquatic pollution and have become rare in many foraging areas where they were once abundant. Loss of such insect populations could prove disastrous for insectivorous bats (Tuttle 1979). The concerns discussed in the section on Indiana bats, above, pertain to gray bats as well.

Potential impacts of military training, testing, and natural resources management

A Biological Assessment on Fort Leonard Wood, MO, considered toxic effects on gray bats from HC smoke pots, terephthalic acid pots, Malathion and Dursban (3D/Environmental 1996a). The risk to gray bats was considered to be identical to the risk to Indiana bats (see above); within 10,000 meters of HC pots, and 2,000 meters of terephthalic pots or Malathion release, gray bats are vulnerable to toxic effects through inhalation. Risk due to ingestion or dermal exposure is reasonable to suspect but unquantified at this time.

Fort Leonard Wood attempted to videotape the reaction of a gray bat maternity colony to military-generated sounds within the maternity cave. Unfortunately, the colony did not remain roosting in a location where the video equipment could record their behavior, so no data were collected (3D/Environmental 1996a).

No studies have specifically quantified hearing sensitivity in gray bats, nor compared such data to the sounds created by military activities. Some research on little brown bats has been conducted and may serve as an estimate. Shimozawa et al. (1974) established that echolocation sounds and audiograms of little brown bats and gray bats are essentially the same. It is thought that sensitivity to sound correlates to the peak frequency range used during echolocation (Suthers 1970). For little brown bats, and presumably gray bats, the peak frequency has been measured at 45 kHz (Fenton and Bell 1981), with peak sensitivity in little brown bats measured at 40 kHz (Dalland 1965). Such information could be compared to the audio characteristics of various activities to assess potential sensitivity. Such an approach was used during the biological assessment for ongoing military activities on Fort Leonard Wood, and concluded that gray bats may be affected by frequent exposure to certain ranges, at distances of 100 to 500 meters (3D/Environmental 1996). Schmidt and Joermann (1986) discovered that noise of similar frequencies to echolocation calls only slightly impaired the ability of bats to echolocate (through interfer-

ence). Bats tend to alter the call frequency and intensity of their own sounds to help discriminate between their own sound and the noise.

Risks to gray bats from smokes, obscurants, and pesticide use are thought to be similar to that discussed above, for Indiana bats.

Gray bats prefer caves located near rivers, which exposes the bat colony to risk from man-made impoundment of the river system. Tuttle (1979) documented reports of important bat caves flooded by the impoundment of nearby waterways. Even if bats are not present upon initial impoundment, the strong roost fidelity and specific roost requirements make it unlikely that a displaced colony will relocate successfully (Tuttle 1979).

Hawaiian Hoary Bat

The Recovery Plan for the Hawaiian hoary bat (USFWS 1998b) contains the following quote from Kepler and Scott (1990): “Whether the hoary bat has declined because of introduced predators, agricultural practices, deforestation, or other human induced stresses is completely unknown.” Indeed, there is no available data directly related to inferred declines in the Hawaiian hoary bat population.

Lesser Long-nosed Bat

Potential causes of population decline

Loss of paniculate agaves and columnar cacti that provide forage for the lesser long-nosed bat comprise the major threat to this species during its summertime occurrence in the United States. These plant species enjoy some limited protection under law, but protection is not complete and a continuing loss of forage plants and related habitat in Arizona and New Mexico continues. To some degree, legal protection is limited by a lack of knowledge about what is needed to provide foraging habitat that will sustain populations. Loss of foraging habitat is very significant in Mexico and creates an important concern for conservation of the species (USFWS 1997).

There are 16 known major roost sites in Arizona and New Mexico supporting the lesser long-nosed bat. Ten years ago, the estimated number of bats occupying these sites was more than 200,000. Thus, each roost site may provide protection for large numbers of bats and any disturbance or damage to roost sites could have significant impact on the species. Lesser long-nosed bats appear to be highly sensitive to human disturbance. Instances are known in which a single brief visit to an occupied

roost caused a high proportion of the bats to abandon the roost temporarily. Such sensitivity indicates that alternative roost sites may be critical when disturbance occurs (USFWS 1997).

5 Interpretation of Risks

Issues Related to Migratory Behavior

An important question about installation bat populations is their whereabouts and degree of protection during migration, swarming, staging, and overwintering. Army installations provide habitat to endangered Indiana, gray, and lesser long-nosed bats in the summertime. However, these same populations are exposed to unknown risks during the remainder of their annual cycle, which includes very vulnerable periods, such as migration, hibernation, spring staging, and autumnal swarming. In most cases, installation biologists do not know where the bats migrate or hibernate. The Army has no control over the status of protection for the bats once they leave the installation. A decline in these populations could occur due to stressors or habitat loss during the summertime, or due to stressors or habitat loss during migration or hibernation. Yet, a decline in these populations, regardless of cause, may lead to consequences for training on the installations during the summertime.

There is evidence that processes at a regional scale are influencing Indiana bat population counts. Clawson (2002) summarizes several decades of census data from the entire range of Indiana bats and concludes that overall, the southern population had declined by 80 percent over the past 40 years. In contrast, the population in the northern part of the range had increased 30 percent, although the increase was not sufficient to offset losses in the south (Clawson 2002). Such patterns imply that processes occurring over large geographic areas, and not necessarily limited to summer ranges of the Indiana bat (such as maternity habitat on a single Army installation) could be important. Local management of summer populations is still essential, and this document does not suggest otherwise. Yet, understanding the risk to bat populations over larger geographic areas (based on migratory patterns) and examining the potential for influencing protection of bats during migration and hibernation may reduce population losses due to stressors beyond the control of the Army. Such efforts also could place Army habitat and management efforts in a regional context, within, possibly, a region of general increase in populations, or, a region of general decline of the species.

Alteration of Indiana Bat Habitat

Based on known and suspected life history and habitat requirements of the Indiana bat, it is important to consider the potential for military mission activities and natural resources management to affect the following:

- occupied maternity roost trees,
- active but unoccupied maternity roost trees,
- potential maternity roost trees,
- availability or quality of roosting sites,
- availability or quality of foraging habitat near maternity areas or hibernacula.

The Fish and Wildlife Service considers destruction of trees greater than 9 inches (22 cm) dbh as a serious threat to Indiana bats, because individuals or groups of bats may be killed by the felling or burning of live or dead trees in which they were roosting. Indiana bats utilize summer habitat and tree roost sites between April 15 and September 15 (e.g.,USFWS 1998a, 1999a, 2004). The highest probability for direct mortality exists between May 1 and August 15, when nursing females and non-volant young are most likely to be using roost trees. Many Biological Opinions, especially those written for National Forest landowners, frequently state that bats would be most vulnerable to death during the felling or burning of the roost tree, and also could potentially be injured or killed if high concentrations of smoke entered the roost space during prescribed burning in their habitat (e.g., USFWS 1999d,1999e, 2001). The Service also states that in cases involving adult bats, it is highly likely that the noise and vibration of chain-saws on the tree or the noise and smoke of nearby fire would successfully wake the bats and provide them the opportunity to escape to alternative roost sites. Belwood (2002) reported on the fate of a maternity colony of Indiana bats whose roost tree was cut down in 1996. This dead tree was cut down on private suburban property to prevent damage to a home. No bats were observed exiting the tree during its felling. The homeowners noticed and collected one dead female Indiana bat, three dead pups, and 30 living pups from the ground near the tree after it was felled. Living adult females were observed under the bark of the felled tree (it appears that they did not flee), and these individuals remained there until dark. At that point, the adults emerged and flew to the location of the living pups, who had been relocated to a bat box that had been mounted to a nearby tree. No bats, dead or alive, were observed in the area the following day or at any time over the next 2 weeks. However, 5 weeks later, 15 bats were observed emerging from under the loose bark of a different (suspected) roost tree at nightfall. These were believed to be members of the same colony, apparently remaining faithful to their maternity range and relocating in an alternative roost despite the catastrophic loss of their occupied roost tree (Belwood 2002). Humphrey et al. (1977) documented mother bats relocating their offspring among different sec-

tions of bark on a single tree, while Kurta et al. (1996) documented frequent roost-switching by lactating females, suggesting that females do have the ability to relocate young when needed. Thus, from one perspective, given the widely scattered pattern of Indiana bat maternity colonies throughout their range, the limiting characteristics of suitable roost trees, and evidence that colonies with young are capable of surviving the destruction of a single roost tree, the issue of destroying roost trees may not appear highly critical. However, widespread loss of suitable forest and roost trees, especially when converting forest to other land uses, would certainly impact the species significantly. It is important to understand that the USFWS considers this a critical issue for ongoing conservation of the species. The uncommon, accidental loss of a roost tree may not kill an entire colony. The presence of alternate roosts buffers against this stressor. However, disregard for this scattered and crucial resource, or habitat destruction over a larger spatial extent, removing all roost options, would lead to impacts at a population/species level.

Actions that result in the modification or removal of active roost trees, potential roost trees, or of roost trees not in use may adversely impact the quantity and quality of summer roosting habitat. Previously used roost sites are important for reproductive success (Humphrey et al. 1977). Recent modeling efforts have identified the presence or density of roost trees as the one factor that best predicts the presence of Indiana bats (Farmer et al. 2002, Miller et al. 2002). By focusing on protection and enhancement of roosts, species managers can efficiently contribute to the conservation of the species. If known roost trees are removed, females that are already stressed by migration and pregnancy must search out new roost sites. Activities likely to negatively impact the roost tree resource include clearing of forests, burning of trees during prescribed burning activities, or the modification of surrounding forest habitat conditions such that potential roost trees are no longer suitable for roosting use. Loss of roost sites would force the bats to search for new roosting habitat and would likely place additional stress on the bats at a time when their energy reserves are already reduced following migration and during pregnancy.

Cool winter burns during the time of year in which Indiana Bats are not using summer roost or foraging sites rarely destroy roost trees since they target the lower understory and herbaceous layers of habitat. They have little to no impact on Indiana bats.

Hot growing season burns can destroy future or present roost snags, but a fire of this nature will also likely kill enough mature trees to create additional snags. Existing trees with value as roost resources can be protected by clearing fuels from the base of these trees. Such fires also kill much midstory and understory growth, opening up habitat and improving both roosting and foraging conditions. It is important to not conduct hot growing season burns during months when young bats

are not yet able to fly. Site preparation burns are often hot summer burns that can remove potential roost trees. Standing timber is reduced before the burn is conducted. Although some residual trees are removed, others are killed and provide roost habitat in the near future.

Stressors to Indiana Bats and Gray Bats

It is important to consider the following risks to Indiana bat and gray bat resulting from military mission activities and ongoing natural resources managment:

- Alteration of insect food base through chemical toxins, water pollution, stream degradation, or changes to supporting plant communities.
- Stress or death to bats from airborne toxins.
- Stress to bats from noise.
- Disturbance of foraging, hibernation, and swarming behavior.
- Alteration of physical conditions in hibernacula.

It is very difficult to assess actual risk to endangered bats from toxins released during military training or land management activities. A recent ecological risk assessment (Smith in prep) provides mathematical equations for estimating installation-specific concentrations of smokes and obscurants in soil, plant foliage, terrestrial insects, and aquatic insects with the specific objective of evaluating risk to selected endangered species, including the Indiana and gray bats. This effort did not provide quantified results for every installation with documented Indiana bats, but provided dozens of calculations for three representative installations, Fort Campbell, KY; Fort Knox, KY; and Fort Leonard Wood, MO. Smith (in prep) summarized the quantity of smokes and obscurants reported for each installation during the year 2002 (Table 3). He estimated risk by calculating the concentration of fog oil that could be expected in plant tissue (through aerial deposition), terrestrial insects (through ingestion of plants), and aquatic insects (through contamination of aquatic sediments). For colored smokes, he estimated the concentration expected in plant tissues (through root uptake) and terrestrial insects (through ingestion of plant tissues). He used recognized EPA methodologies for estimating the values of toxin concentration that are expected to produce an effect for the Indiana bat and the gray bat; estimates were based on data from other species, and are detailed in his document. An evaluation of risk was then calculated for each installation, based on the types and quantities of smokes and obscurants reportedly used, and the area over which these chemicals are typically deployed. Results for the three installations are as follows: Fort Campbell, KY, data indicated that white phosphorus presents a fairly high risk to both the Indiana bat and the gray bat. No other smokes and obscurants presented significant risk, based on the methodology used. Fort Knox, KY, data indicated a low risk of toxicity from fog oil to the Indiana bat, and

no risk to the gray bat. For Leonard Wood, MO, data suggest a high risk to both species of bat from fog oil, (as well as several toxic components of military shells, heretofore not discussed, see Smith in prep). However, data was not available to estimate risks for most of the smokes and obscurants used on Fort Leonard Wood. None of the three installations presented data that suggest a danger from colored smokes. Smith's work strongly suggests that fog oil creates the most likely risk to the Indiana and gray bats, based on contamination of plant tissues and insects.

Table 3. Quantities of smokes and obscurants reported used on three installations during 2002. (summarized from Smith in prep).

Installation	Quantity of "Smokes and Obscurants" (Weight in kg)	Quantity of Colored Smokes Weight in kg
Fort Leonard Wood, Missouri	7255.71*	9642.70*
Fort Knox, Kentucky	537.44	707.80
Fort Campbell, Kentucky	18767.00	204.95
* adjusted for 10% dud rate		

If a substantial amount of smoke from fire or military operations entered a hibernaculum or a gray bat maternity cave during bat occupation, adult or juvenile bats could be potentially harmed or killed. The same risk exists in the case of concentrations of pesticides. There is a high level of awareness and avoidance of these risks on military installations already. The potential for acute poisoning of this nature is very low. However, the potential for sublethal impacts that indirectly reduce population viability is unknown at this time. Potential for impacts from these same chemical sources exists for Indiana bats in summer roosts within the forested habitats of installations where they occur. It is extremely difficult to locate occupied roost trees, so preventing exposure can be difficult. However, the impact from exposure in one location may affect only a small number of bats. It is not known how many Indiana bat roosts may exist very close to locations involving dense smoke or chemical usage, nor is the potential for chemical exposure under tree bark known. As a result, the use of dangerous chemicals has been curbed on several installations as a protective measure (e.g., Tetra Tech 2001 and 2002).

Insectivorous bats depend upon their insect prey base for survival. In addition to toxicity from chemical uptake within the bodies of insect prey, ecological changes that that significantly reduce numbers of insects available could impact the Indiana or gray bat. Severe soil erosion and stream sedimentation leads to a reduction in aquatic insects, which reproductive females utilize to a greater extent than other classes of bats. Insecticide use has strong potential for reducing prey availability, and may lead to secondary toxicity in bats that consume sprayed insects. Changes to plant community composition and structure could alter insect populations as well. For example, clearing of understory (prescribed burning) and some mild to

moderate reduction of overstory cover can increase insect supply and improve food supply.

Contaminated runoff from ranges could pollute ponds, waterholes, or natural collections of water, which may be used as drinking sources by bats.

6 Restrictions on Military Installations and Other Representative Lands

This chapter summarizes known restrictions in place on Army installations instituted in reaction to documented or suspected impacts to endangered bat species. A few restrictions currently in place for Marine Corps lands are included because they provide additional noise-related examples. For forestry operations, this chapter summarizes the general nature of restrictions in place on National Forest lands and installations having forestry programs. Although the restrictions summarized here are likely to be in place on installations known to be occupied by the various bat species, some variation in imposed restrictions is also possible.

Restrictions Related to Smokes and Obscurants

Camp Atterbury (Pruitt 1998) and Fort Leonard Wood (3D/Environmental 1996a) have documented restrictions on the use of smokes and obscurants based on risks to endangered Indiana and/or gray bats. The use of pots and grenades containing HC has been eliminated on both installations. The use of pots and grenades containing TPA is restricted from deployment within 36 m of any maternity trees and within 120 m of waterways, and only to daylight hours during the summer maternity season. At Camp Atterbury, TPA restrictions near waterways encompass 8616 acres (3486.8 ha) or 32.1 percent of the installation's usable training land (Tetra Tech, Inc. 2002; see Figure 10). At Fort Leonard Wood, restrictions on TPA use near waterways encompass 7072 acres (2862 ha) or 11.4 percent of the installation. Four Indiana bat hibernacula and two gray bat maternity caves are known to occur on Fort Leonard Wood. Concentric zones of limited human activities have been imposed around these caves during the periods of time in which the caves are in use by endangered bats. The first zone is called the "restricted zone" and extends in a 531-foot (162-meter) radius around each cave opening, for a total area of complete protection totaling 20 acres (8.1 ha). From August 1 until May 31, at Indiana bat hibernacula, no military activities or development is allowed within the restricted zone, except for foot maneuvers. The first "buffer zone" extends from a 531- to 1498-foot (162- to 457-meter) radius; within this zone, most activities involving smokes and obscurants are prohibited. At the Indiana bat hibernacula, these restrictions are in place from March 15 until April 30 and from September 1 until October 15, from 1 hour before sundown to 1 hour after sunrise. Restrictions within these zones

are in place from April 1 until October 31 at the two gray bat hibernacula. These two zones equal 321.4 acres (130 ha) of training land (0.52 percent of the installation) during the summer when gray bat maternity colonies are on site, and 692.6 acres (280.3 ha, 1.1 percent of the installation) during the winter when Indiana bats are using their hibernacula. A second buffer zone extends from a 1498-ft radius to 6337-ft radius (457-m to 1933-m radius). It is unclear how use of smokes and obscurants may be affected by this buffer zone; restrictions are stated as "disruptive activities are to be minimized within this zone, especially during spring and fall" (3D/Environmental 1996a).

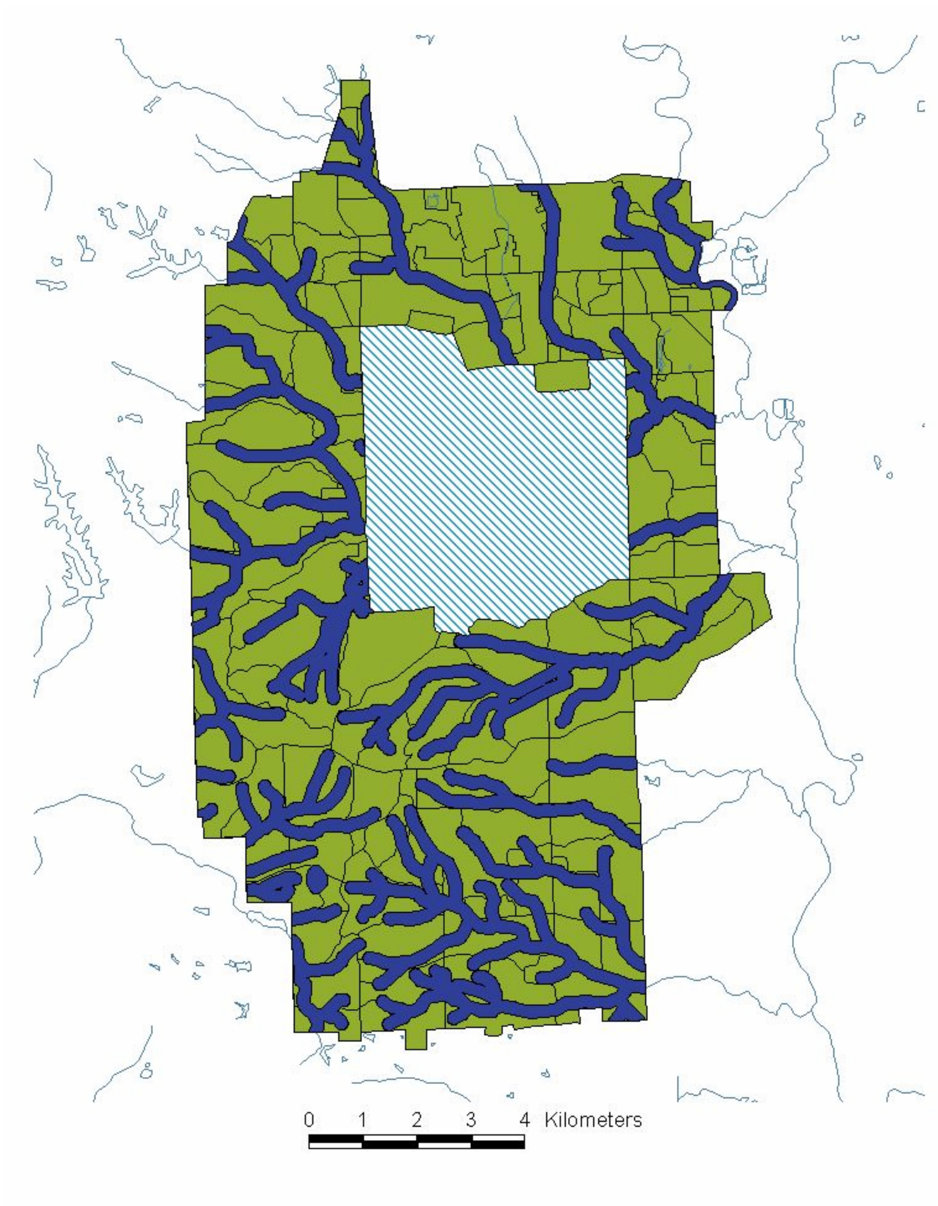

Figure 10. Nighttime restrictions on the use of TPA smoke grenades and pots within 120 meters of perennial waterways (blue) at Camp Atterbury (green) during the summer maternity season. The Impact Area is shown in diagonal hashing.

Restrictions Related to Pesticides

All installations follow the legal requirements for pesticide application, such as following the label instructions and using proper quantities. In addition, Army installations attempt to implement integrated pest control strategies prior to application of chemicals. Army installations consider rotation of pesticide classes to reduce pest resistance, and when possible, utilize precision farming to match pesticide use to actual need.

In addition, the following restrictions are in effect on Newport Chemical Depot (McWilliams-Munson 1999):

- A 10-meter buffer strip is required between the application of herbicides and forested vegetation.
- A 20-meter buffer strip is required between the application of insecticides and forested vegetation.
- Aerial application of pesticides is prohibited.
- Application of pesticides in gusty wind or when wind speeds exceed 5 mph should be avoided.
- Ultra low volume and mist applications should be avoided.
- Non-chemical means of reducing pest population will be employed, such as crop rotation, use of natural pest predators and diseases, pest scouting to focus chemicals only where required, and rotation of pesticide classes to reduce any resistance to chemicals.

The following restrictions are in effect on the Iowa Army Ammunition Plant (Tetra Tech EM, Inc. 2001):

- Pesticide application is limited to the period between 30 minutes after sunrise and 30 minutes before sundown.
- Pesticide application in gusty winds or when the wind speed exceeds 10 miles (16 km) per hour must be avoided.

Restrictions Related to Noise and General Human/Military Activities

Four Indiana bat hibernacula and two gray bat maternity caves are known to occur on Fort Leonard Wood. No activity is ever allowed within these caves. Concentric zones of limited human activities have been imposed around these caves during the periods of time in which the caves are in use by endangered bats. The first zone is called the "restricted zone," and extends in a 531-foot (162-m) radius around each cave opening, for a total area of complete protection totaling 20 acres (8.1 ha). From August 1 until May 31, at Indiana bat hibernacula, no military activities or development is allowed within the restricted zone, except for foot maneuvers. The first

"buffer zone" extends from a 531- to 1,498-foot (162- to 457-m) radius; within this zone, noise simulation is prohibited. At the Indiana bat hibernacula, these restrictions are in place from March 15 until April 30 and from September 1 until October 15, from 1 hour before sundown to 1 hour after sunrise. Restrictions within these zones are in place from April 1 until October 31 at the two gray bat hibernacula. These two zones equal 321.4 acres (130 ha) of training land (0.52 percent of the installation) during the summer when gray bat maternity colonies are onsite, and 692.6 acres (280.3 ha, 1.1 percent of the installation) during the winter when Indiana bats are using their hibernacula. A second buffer zone extends from a 1,498-ft radius to a 6,337-ft radius (457-m to 1933-m radius). It is unclear how noise generation or general military activity may be affected by this buffer zone; restrictions are stated as "disruptive activities are to be minimized within this zone, especially during spring and fall" (3D/Environmental 1996a). In addition, in order to better protect the Indiana bat during hibernation, there are restrictions on detonation of charges from August 1 until May 31. Charges of 250-lb size must be detonated at least 250 m away from hibernacula, while charges of 1,000-lb size must be detonated at least 1000 ft (305 m) away from hibernacula (3D/Environmental 1996a).

Camp Atterbury recognizes that more than 68 percent of the land area occupied by two training areas is suitable Indiana bat summer habitat, so the installation has determined that military training activities in those two training areas, which total 2845.4 acres (1151.5 ha), will not increase in intensity. In addition, 777 acres (314.4 ha) have been designated as Indiana Bat Management Zones as mitigation for the development of a multipurpose training range on Camp Atterbury; within these areas, military activities are permitted, but off-road maneuvers are minimized and tracked vehicles must stay on existing roads and trails (Tetra Tech, Inc. 2002).

On Fort Huachuca, night firing of small arms is prohibited on three ranges during the period of July 1 through October 31 each year. Extensive regulations are in place on this installation to minimize the risk of accidental fires and to ensure rapid response in the case of accidental fire, since fires can destroy essential food resources of the lesser long-nosed bat. Areas identified as agave management tracts are protected in part by active fire management and exclusion of pyrotechnics, and tracked and off-road vehicle access. From July 1 through October 31, nighttime training of any sort is prohibited in these areas, as well. Rocket-assisted take-offs of unmanned aerial vehicles at the Black Tower launch site could affect foraging behavior of nearby lesser long-nosed bats. Therefore, nocturnal rocket-assisted launches are prohibited at the Black Tower site from July through October when the bats are known to be on post. Low-level helicopter flights are also prohibited from July 1 through October 31 within 350 feet (106.7 m) of day roosts of the bat (USFWS 1999b).

The Marine Corps Air Station at Yuma, which uses a number of public lands and airspaces in Arizona, has agreed to the following restrictions of military air flights in consideration of the lesser long-nosed bat: (1) no flights over known maternity day roosts of the species except for fixed-wing flights at greater than 1,500 feet (457.2 m) altitude, and (2) between March 15 and July 15 of each year, all helicopters will remain within restricted zones of airspace (USFWS 2003).

Restrictions Related to Habitat Alteration

In 1998, the USFWS issued a Biological Opinion on the clearing of approximately 80 acres (32.4 ha) of forest habitat on Fort Knox. The USFWS required that tree removal, or at least the removal of all live and dead trees 9 inches (22 cm) dbh or greater, had to be conducted between September 15 and March 15, to minimize direct mortality to roosting young Indiana bats (USFWS 1998a).

In 1998, the USFWS issued a Biological Opinion on the removal of 246.3 acres (99.7 ha) of suitable Indiana bat summer habitat at Camp Atterbury, IN (Pruitt 1998). The USFWS required 667 acres (270 ha) to be protected as Indiana Bat Management Zones, to be removed from commercial timber rotation, and to be managed for Indiana bat conservation as well as the then-current levels of military activities. Also, a landscape-scale forest management policy was requested by USFWS, to provide a sustainable source of suitable summer habitat for the Indiana bat on post. A radiotelemetry study to locate roost trees and characterize habitat around roost trees was also requested (Pruitt 1998).

All installations with documented populations of Indiana bats and active forest management programs comply with the USFWS guidelines for silvicultural practices to conserve the species. These guidelines include limitations on sizes and extent of clearcuts, the removal of large diameters trees, the removal of snags, and protection of waterways from erosion. On lands known to harbor endangered Indiana bats, forest managers are required to protect all snags, and most large-diameter trees, especially of species known to be selected as roost sites by maternity colonies of the Indiana bat.

USFWS requires that a minimal number of potential roost sites be left following harvest activities, stated in terms such as “at least three snags over 9 inches dbh” or “at least 10 to 15 square feet of basal area per acre of suitable roost trees be retained, with each tree being at least 6 inches dbh” (USFWS 2001). Sometimes, the ‘leave trees’ are specified as greater than 11 inches (27 cm) dbh, or 20 inches (49 cm) dbh, or 22 inches (54 cm) dbh. Sometimes, six trees per acre are specified. Often, a number of additional, large live trees from the list of preferred roost species are spe-

cifically protected as well. The specifics about how many trees, and of what sizes, is variable among the different USFWS field offices, and even among different biological opinions, based on the specifics of the situation.

During clearcuts, snags are most often protected by requiring a minimal basal area of leave trees clustered around snags to prevent windthrow. For example, the Mark Twain National Forest is required to leave a minimum basal area of 15 around large live trees, snags and "den trees." Similarly, during shelterwood cuts, a minimum basal area of 25 is required, along with the requirement that leave trees be left along drainages and to otherwise provide habitat connectivity for bats.

Often, a conservation goal is specified in terms of canopy cover, usually defined as between 60 and 80 percent cover. Occasionally, thinning to achieve this forest structure is recommended (e.g., USFWS 2001). More often, it is a requirement to not reduce the canopy below this range of values.

In the Nantahala/Pisgah National Forest, NC, canopy openings within 30 feet (9.1 m) of intermittent streams are limited to no larger than the size of a single treefall, and must be at least 75 feet (22.9 m) apart. Within 30 feet (9.1 m) of perennial streams and other bodies of permanent water, no standing trees of any condition should be removed. At least 60 percent cover must be maintained in the remaining riparian area.

Fort Huachuca experiences restrictions and additional management burdens relating to the management of agave Management Areas, to provide a sustainable food supply for the lesser long-nosed bat. The most important consideration is protection of the plants from fire, along with protection from extensive trampling, each of which can affect survival and reproduction of individuals (Howell and Robinett 1996). Restrictions include: no off-road vehicle activity, no pyrotechnics, no tank training in these areas on the West Range, active suppression of fires unless the fire return interval is approaching the natural interval of 10 years, and reduced access for dismounted training. Additional land management requirements are in effect for the entire post: no planting of non-native grasses or other plants, since such alterations in plant community can affect fire dynamics, a limit of 20 percent mortality to agave populations during intentional fire activities such as prescribed burns, avoidance of off-road vehicular use during fire management activities, avoidance of intensive fire management activity within 0.25 miles (0.4 km) from known day roosts from July 1 through October 31, monitoring of Palmer's agave populations on the West and South ranges, and provide environmental awareness to reduce damage to the bat food supply (USFWS 1999b).

7 Suggested Future Research

A summary of information relevant to this section is presented in Table 4 (page 76). Representative installations are listed, along with documented endangered bat records, a summary of restrictions on post, and a summary of the following eight research focus areas (discussed below) that could potentially benefit each installation.

Geographically and Temporally Specific Study of Indiana and Gray Bat Exposure to Threats Beyond Army Lands

Twelve military installations are known to have Indiana bats onsite, but the species could potentially occur on as many as 51 others. Seven military installations are known to have gray bats onsite; as many as 11 other installations are known to have maternity caves or hibernacula within the same or adjacent county (Table 1, page 26).

Documented indications of level of interest from USFWS

The 1999 draft recovery plan for the Indiana bat requests that the following research be conducted (USFWS 1999a):

1. Determine associations of summer range with hibernacula,
2. Monitor the status of populations in summer,
3. Determine summer habitat trends.

Research recommendations

A geographic and temporal analysis of endangered bat landscape use patterns and seasonal movement patterns would clarify the role of DoD lands within the cycle of bat life history requirements. Land managers need to know the extent to which bats utilizing military lands for roosting or foraging habitat are vulnerable to land management policies or habitat degradation on nearby lands owned by other public or private landowners. Managers also need to the location of the winter hibernacula of the bats captured on Army installations during the summer season. An assessment of exposure and vulnerability based on geographic and temporal relationships between bat natural history, land ownership patterns, and military land management and military training patterns would provide a foundation for the best possible research planning and programming to reduce conflict between the training mis-

sion and endangered species conservation. It would also reveal potential opportunities for proactive multiple landowner agreements that could stabilize endangered bat populations currently considered the responsibility of the Army.

Geographic and temporal assessment would require netting or trapping of endangered bats combined with radiotracking and/or passive integrated transponder (PIT) studies in order to describe landscape-wide habitat use during spring, summer, and fall, and to identify the migration routes and hibernacula used by bats when not on Army installations. Once this information is known, the Army will be in a position to pursue management actions or agreements with other landowners to promote the conservation of populations found on Army lands. The data gathered in a geographic/temporal study would support a simple geographic analysis to provide quantitative estimates of the spatial overlap between bat habitat use and military mission requirements.

Further Study on Impacts from Smokes and Obscurants for the Conservation of Indiana and Gray Bats

Twelve military installations are known to have Indiana bats onsite, but the species could potentially occur on as many as 51 others. Seven military installations are known to have gray bats onsite; as many as 11 other installations are known to have maternity caves or hibernacula within the same or adjacent county (Table 1, page 26).

Number of installations currently experiencing restrictions, and nature of restrictions

Camp Atterbury and Fort Leonard Wood have documented restrictions on the use of smokes and obscurants based on risks to endangered Indiana and/or gray bats. The use of pots and grenades containing HC has been eliminated on both installations. The use of pots and grenades containing TPA is restricted from deployment within 36 meters of any trees and within 120 meters of waterways, and to daylight hours only during the summer maternity season. On Fort Leonard Wood, TPA usage is also restricted within 457 meters of gray bat maternity caves. See Chapter 6 for more details.

Brief summary of available data related to this issue

An ecological risk assessment comprised a part of the biological assessment for on-going mission activities on Fort Leonard Wood, Missouri. The results included risk contours of varying distances from release of HC and TPA materials. A Biological Assessment prepared in 1996 for Fort Leonard Wood focused more directly on toxicity from smokes and obscurants, and concluded that TPA could be used if certain restrictions were applied (3D\Environmental 1996a). Ongoing toxicological monitoring of bats on Fort Leonard Wood required the sacrifice of surrogate bats for chemical analysis to identify the concentrations of TPA and its metabolites within various tissues. Data through the year 2000 indicated that biogenic sources were responsible for measured levels of TPA, since bats from reference sites contained levels of contamination similar to bats from Fort Leonard Wood. The 2002 Biological Assessment for Camp Atterbury that included an assessment of risk to Indiana bats from TPA compounds largely drew its conclusions from the earlier work and biomonitoring data from Fort Leonard Wood (Tetra Tech, Inc. 2002). A significant complication is that the chemical formulations and production standards are continually being updated in an attempt to reduce smoke and obscurant toxicity.

Documented indications of level of interest from USFWS

Risk from smoke and obscurant devices is not specifically mentioned as a research need in the Indiana or gray bat recovery plans. In the biological opinion for development of a multi-purpose range complex on Camp Atterbury, the USFWS requests additional research related to the toxic effects of TPA devices if biomonitoring of bats on Fort Leonard Wood indicates that results of the environmental risk assessment are overly optimistic (Pruitt 1998).

Research Recommendations

An Army study on the impacts of fog oil concluded that more research was needed (Getz et al. 1996). The report identified a lack of long-term data on exposure and toxicity — no data are available to create models for long-term effects. This lack of data exists for HC and TPA as well. Sensors placed in the field in locations where bats would potentially encounter fog oil deposition could be used to gather basic data to create long-term exposure models. Alternatively, validation and refinement of existing short-term models could be combined with spatial and temporal modeling to project long-term patterns of exposure and used as a basis for laboratory studies of long-term toxic effects on a surrogate species.

Models that predict exposure to fog oil over the short time frames immediately associated with training exercises do exist, but almost none have been field tested or

validated. Getz et al. (1996) reviewed several models that predict air and substrate concentrations of oil following smoking operations. Policastro et al. (1989) and Liljegren et al. (1989) evaluated fog oil models, but only Liljegren et al. (1988) have provided empirical data on environmental concentrations of fog oil.

The highest priority for future research related to impacts from smokes and obscurants should be the assessment of impact on insect population levels, including aquatic insects. Lab-derived exposure/toxicity response functions for population-level measurement endpoints should be generated under relevant environmental conditions and coupled with dispersion models to estimate population-level effects. The results of this research would provide a better understanding of the effects smokes and obscurants have on insect populations, thereby allowing installation trainers, natural resource managers, and EPA and USFWS regulators to make informed decisions about smoke and obscurant use on installations.

Further Studies of Pesticide Impacts (and other issues related to prey availability) for the Conservation of Indiana and Gray Bats

Twelve military installations are known to have Indiana bats onsite, but it could potentially occur on as many as 51 others. Seven military installations are known to have gray bats onsite; as many as 11 other installations are known to have maternity caves or hibernacula within the same or adjacent county (Table 1, page 26). It is assumed that all installations currently use or, in the future, may desire to use some pesticide applications (see Table 2, page 31).

Although it seems as though this issue would affect all Army installations, the use of pesticides has dropped sharply in recent years. This research topic is not one that is specific to the military.

Number of installations currently experiencing restrictions, and nature of restrictions

The following restrictions are in effect on Newport Chemical Depot (McWilliams-Munson 1999):

- A 10-meter buffer strip is required between the application of herbicides and forested vegetation.
- A 20-meter buffer strip is required between the application of insecticides and forested vegetation.
- Aerial application of pesticides is prohibited.
- Application of pesticides in gusty wind or when wind speeds exceed 5 mph should be avoided.

- Ultra low volume and mist applications should be avoided.
- Non-chemical means of reducing pest population will be employed, such as crop rotation, use of natural pest predators and diseases, pest scouting to focus chemicals only where required, and rotation of pesticide classes to reduce any resistance to chemicals.

The following restrictions are in effect on the Iowa Army Ammunition Plant (Tetra Tech EM, Inc. 2001):

- Pesticide application is limited to the period between 30 minutes after sunrise and 30 minutes before sundown.
- Pesticide application in gusty winds or when the wind speed exceeds 10 mph must be avoided.

Brief summary of available data related to this issue

The Biological Opinion for agricultural pesticide application on Newport Chemical Depot states that "very little information has been documented with respect to the effects of "modern day" pesticides on bats or their food base." (McWilliams-Munson 1999). However, more than four pages of review and analysis of the literature base on the topic are presented in this same BO and provide initial information related to the topic. The Biological Assessment conducted for Fort Leonard Wood in 1996 provided risk contours for toxic exposure of bats to Malathion and Dursban (3D/Environmental 1996a). Subsequent biomonitoring on Fort Leonard Wood provided laboratory measurements of Malathion and Dursban body burdens in surrogate bats collected from the installation.

Documented indications of level of interest from USFWS

The 1999 draft recovery plan for the Indiana bat requests that the following research be conducted (USFWS 1999a):

- Determination whether Indiana bats are being contaminated by chemicals in the environment (specifically, pesticides),
- Determination of the concentrations of chemicals in Indiana bat tissues, guano, and prey samples,
- Determination of the effects of chemical contamination on Indiana bat reproduction and survival.

A strong interest by USFWS on this issue is indicated by the level of information incorporated in the literature review within the BO for Newport Chemical Depot (McWilliams-Munson 1999).

Research Recommendations

Research has been conducted on the effects of agricultural chemicals, but almost all available data concern chemicals that are now banned in the United States. Currently, applications of pesticides are restricted from certain areas, and aerial spraying is sometimes prohibited, such as on Newport Chemical Depot. But in general, no specific legal pesticide has been banned from Army lands based on known or suspected impacts to Indiana or gray bats. For chemicals widely used on Army installations at the present time, the most information is available for Malathion and Dursban. Both of these chemicals are nonsystemic organophosphorous insecticides that are believed to be safe for mammals at recommended use levels. Dursban is important for the military mission, since it is used to reduce disease-bearing tick populations within bivouac areas. However, it is not an aerosol spray, and it is hand-applied in focused areas. It is unlikely that endangered bats are exposed to Dursban. Sublethal toxic effects from chemicals on reproduction and fitness could be significant when animals are exposed (Hoffman et al. 1995), and bats have demonstrated more severe non-lethal effects when compared to mice in one study (Clark and Rattner 1987).

It is important to note that although direct or indirect impacts to endangered bats from agricultural pesticides are not documented, they are widely considered likely in the overall pattern of population decline of both the Indiana bat and the gray bat, based on statements by the USFWS in numerous Biological Opinions and in the recovery plans of the Indiana Bat and Gray Bat. It may be important to target future research to evaluate the relative risk to bats from direct sublethal toxic effects compared to possible indirect effects on bats' insect food supply. If one or both pathways cause impacts to bat populations, management recommendations could be focused appropriately, based on those results.

Toward this end, future research should include measurement of insecticide levels in bat prey species, from either ingestion or deposition. It would be desirable to measure any change or reduction in prey population or community dynamics due to contact or environmental contamination from insecticides. It would be important to measure levels of pesticide toxins in the tissues of adult bats and the milk of lactating female bats. Currently, this type of monitoring occurs on Fort Leonard Wood. Each year, several dozen individuals of surrogate bat species are collected and tested for pesticide contamination. So far, levels of Malathion and Dursban, the two chemicals used on Fort Leonard Wood, have not been detected in bat tissue samples (Schmidt et al. 2002). Similar work at other installations may be warranted, depending on pesticide use patterns and the proximity of bat roosting habitat to locations of pesticide application. If contamination of bats were demonstrated, laboratory studies of chronic effects at different levels of contamination would be justified.

Practical recommendations could then be developed for periodic monitoring of body burdens and managing pesticide use to prevent direct impacts.

The study of indirect impacts due to reduced insect prey populations is another area for potential future research. Several possibilities exist. One line of inquiry could focus on changes in vegetation from herbicide application, and the resulting alteration in insect community dynamics. A similar project could evaluate the impacts of invasive alien plant species, which can alter plant communities over potentially large areas, on bats' insect prey base.

Insect populations could also be impacted from sedimentation or contaminated runoff. Gray bats and reproductively active Indiana bats depend on aquatic insects for a significant portion of their diet. If water quality decreases and alters insect population numbers, bats could be affected. It is recommended that research be conducted to measure water quality within known or suspected foraging habitat and compare water quality to insect community characteristics.

Further Studies on Noise Impacts and General Disturbance Impacts for the Conservation of Indiana, Gray, Hawaiian Hoary, and Lesser Long-nosed Bats

Twelve military installations are known to have Indiana bats onsite, but the species could potentially occur on as many as 51 others. Seven military installations are known to have gray bats onsite; as many as 11 other installations are known have maternity caves or hibernacula within the same or adjacent county (Table 1, page 26). One installation provides habitat for the lesser long-nosed bat, but it also potentially occurs on two additional installations. Four installations have documented occurrences of the Hawaiian hoary bat, but the species may actually occur on 25 Army and Army National Guard installations (Table 2, page 31).

Installations currently experiencing restrictions, and the nature of the restrictions:

1. Fort Leonard Wood restricts activities within a 20-acre (8.1-ha) radius around each cave known to contain Indiana bats (during hibernation), or a maternity colony of gray bats (summertime). Within the restricted zone, only foot traffic is allowed. No activity is permitted inside the caves. Prohibition of noise extends to a total distance of 1,932 meters radius around each cave (3D/Environmental 1996a).
2. Camp Atterbury recognizes that more than 68 percent of the land area of two of its training areas are covered by suitable Indiana bat summer habitat, so the installation has determined that military training activities in those two training areas, with a total of 2845 acres (1151.5 ha), will not increase in intensity. In ad-

dition, 777 acres (314.4 ha) have been designated as Indiana Bat Management Zones as mitigation for the development of a multi-purpose training range on Camp Atterbury; within these areas, military activities are permitted, but off-road maneuvers are minimized and tracked vehicles must stay on existing roads and trails (Tetra Tech, Inc. 2002).

3. On Fort Huachuca, night firing of small arms is prohibited on three ranges from July 1 through October 31 each year. Extensive regulations are in place on this installation to minimize the risk of accidental fires and to ensure rapid response in the case of accidental fire, since fires can destroy essential food resources of the lesser long-nosed bat. Sites identified as agave management areas are protected in part by exclusion of pyrotechnics and tracked and off-road vehicle access, and by active fire management. From July 1 through October 31, night-time training of any sort is prohibited in these areas, as well. Because rocket-assisted take-offs of unmanned aerial vehicles at the Black Tower launch site could affect foraging behavior of nearby lesser long-nosed bats, nocturnal launches are prohibited from July through October when the bats are known to be on-post. Low-level helicopter flights are prohibited from July 1 through October 31 within 350 feet (106.7 m) of day roosts of the bat (USFWS 1999b).
4. The Marine Corps Air Station at Yuma, which uses a number of public lands and airspaces in Arizona, has agreed to the following restrictions of military air flights in consideration of the lesser long-nosed bat: (1) no flights over known maternity day roosts except for fixed-wing flights of greater than 1500 feet (457.2 m) altitude; and (2) between March 15 and July 15 of each year, all helicopters will remain within restricted zones of airspace (USFWS 2003).

Brief summary of available data related to this issue

Biological assessments conducted for Camp Atterbury and Fort Leonard Wood have evaluated the threats to endangered bats from military-generated sounds, and to a lesser degree, from general disturbances related to military activities (3D\Environmental 1996a, Tetra Tech 2002). A small-scale radiotelemetry study on Fort Leonard Wood indicated that bats do not alter their foraging behavior in response to nighttime training activities. An evaluation of military training impacts on Indiana bats for Camp Atterbury came to the similar conclusion that any impacts to bats from military activities would be rare and probably impact only one or a few individuals (Tetra Tech, Inc. 2002). One male bat was tracked using radio-telemetry during the summer of 2002 on Fort Campbell, KY. This bat was observed foraging and night-roosting in the same location near the Impact Area during three nights when low-altitude helicopter flights and artillery firing occurred. There was no apparent difference in his behavior on these nights with military training, and nights with little or no military training (BHE 2002b).

Studies performed for Fort Leonard Wood to measure reactions of roosting gray bats and hibernating Indiana bats to loud military sounds suffered from various problems and the resulting conclusions must be viewed carefully. Hibernating little brown bats were presented with recorded military sounds at three levels of intensity and two seismic vibrations, all of which were greater than expected and measured intensities within hibernacula on the installation. None of the stimuli resulted in an arousal from four bats in a laboratory setting (3D/Environmental 1996a). An assessment by Camp Atterbury in the 2002 draft BA for ongoing mission activities (Tetra Tech, Inc. 2002) reports that machine gun fire and smoke grenades produce sounds within the auditory range of little brown bats up to 140 dB. It is not known what effect such sounds would have on the auditory systems or behavior of endangered bats.

Dalton and Dalton (1993) investigated the effects of low-altitude military jet flights over a day-roost mine location at Organ Pipe National Monument. No panicked flights, no startle responses, or falling young bats were observed. It is thought that helicopter flights may be more disturbing than fixed-wing aircraft, and the effects of low-level helicopter flights on lesser long-nosed bats has not been examined (USFWS 1999b). In this same document, the USFWS concludes that noise from military weapons fire is unlikely to disturb lesser long-nosed bats. Some training activities, such as bivouacking, could damage populations of agaves, but troops are instructed to avoid areas with agave stands to minimize reduction of food supply for the endangered bat (USFWS 1999b).

Documented indications of level of interest from USFWS

There is no specific request for further research on this topic within the documents available at this time.

Research Recommendations

Studies conducted on Fort Leonard Wood established that very little noise from military training was detectable within cave environments. This type of study could be expanded into a broad survey of the levels of sounds occurring in the roost sites of bat species. Bats roosting in cave environments may not be exposed to significant noise levels. Those roosting in forested environments, such as Indiana bats in the summertime, and Hawaiian Hoary bats, may be exposed to significant noise levels. Once realistic noise exposure levels are measured, laboratory studies could be conducted to measure changes in physiology, auditory abilities, and behavior. In particular, it would be important to evaluate the maternal behavior of female Indiana and Hawaiian Hoary bats, as well as any physiological or behavioral impacts to young. It is uncertain whether pregnant and lactating female bats could be housed

under experimental conditions in such a way as to evaluate maternal behavior and impacts to offspring.

Widespread replication of the Fort Leonard Wood telemetry studies may be useful as well. Studies tracking locations of foraging Indiana bats, sometimes in close association with military training activities, were useful, but limited due to very small sample size. Additional studies of similar design are needed to fully evaluate the potential behavioral changes that may be seen in endangered bats in response to military activity, including noise generation. All four species need to be tracked under as many different conditions as possible, exposed to as many different training exercises as possible, to ascertain whether or not behavior changes in response to training. If significant changes in behavior are seen, an evaluation of the significance of those changes would then be needed as well. For example, if a commonly used foraging range is abandoned in response to nearby military activity, it would be important to evaluate whether the change in foraging location was meaningful—i.e., was food supply lower in the alternative site compared to the more commonly used site?

Further Studies on Swarming Biology for the Indiana and Gray Bats

Number of installations potentially affected

Fort Leonard Wood has four caves within installation boundaries where Indiana bats have hibernated. These would be sites of swarming behavior in the fall, and post-emergence staging in the spring prior to migration (3D/Environmental 1996a).

Two male Indiana bats were captured on Fort Campbell in late August 1998. Indiana bats have been documented roosting in winter and spring in at least 5 caves within 5 miles (8 km) of the installation boundary (BHE 2004). It is possible that Fort Campbell may play some role in providing resources to these bats during the swarming period. Numerous other installations are within close proximity to Indiana or gray bat hibernacula. (See Figures 5 and 7, pages 24 and 29 and Table 1, page 26).

This issue is not a military-unique question.

Number of installations currently experiencing restrictions, and nature of restrictions

Three concentric buffer zones have been created around known Indiana bat hibernacula on Fort Leonard Wood. The smallest zone is 20 acres (8.1 ha) with a radius

of 162 meters, wherein activities are limited to foot traffic only. No military activities are ever allowed within the caves. The second buffer zone extends to a total radius of 1500 feet (457 meters or 65.61 ha); within this zone, most activities involving smokes and obscurants and noise production are prohibited. The third buffer zone extends to a total radius of 6338 feet (1932 meters or1172.6 ha) and protects the bats from habitat alteration and noise generation (3D/Environmental 1996a).

Brief summary of available data related to this issue

Menzel et al. (2001) reviewed the literature base on swarming behavior for the Indiana bat. Very little has been documented for swarming behavior in the gray bat. It is known that bats forage intensively during the swarming period and deposit body fat in preparation for hibernation. The full purpose of swarming behavior as it relates to mating success is not understood. Three studies documented the use of drier, upland habitats during the Indiana bat swarming period as compared to many studies of foraging behavior during the maternity season (Menzel et al. 2001). Limited data suggest Indiana bat foraging becomes restricted to an area within 1.5 miles (2.5 km) of the hibernaculum, by some time in October (e.g., Kiser and Elliot 1996).

Documented indications of level of interest from USFWS

In the 1999 draft recovery plan for the Indiana bat (USFWS 1999a), the USFWS lists a research requirement for determining the significance of swarming sites on survival of the species.

Research recommendations

The period of time immediately prior to and following hibernation is critically important. Gray bats and Indiana bats mate during the fall swarming period, and forage intensively, gaining significant weight in preparation for hibernation. Foraging shifts from summertime home ranges to the landscape within 1.5 miles (2.5 km) of winter hibernacula for Indiana bats (e.g., Kiser and Elliot 1996). Bats remain near the hibernacula again for an unknown period of time post-hibernation, rapidly replacing resources used during hibernation. Telemetry studies and fecal dietary analysis could be used to better elucidate foraging habitat and prey selection during these periods. Once foraging habitat is identified, it could be quantitatively measured and compared to alternative habitat in the landscape, as well as summertime foraging habitat. Management would then be able to promote plant community characteristics near hibernacula that support bat foraging requirements during these critical times. Similarly, it would be useful to understand the insect communities in habitats near hibernacula, whether certain insects are highly selected, and

whether these species are burdened with measurable toxins, especially during late summer or early fall. It is possible that bats become more sensitive to noise or other disturbances during these periods as well, so telemetry studies that evaluate behavior with and without nearby recreational and military activities would be informative.

Further Studies on Summertime Habitat Requirements for the Indiana and Gray Bats

Twelve military installations are known to have Indiana bats onsite, but the species could potentially occur on as many as 51 others. Seven military installations are known to have gray bats onsite; as many as 11 other installations are known to have maternity caves or hibernacula within the same or adjacent county (Table 1, page 26).

Number of installations with documented, related restrictions, and nature of restrictions

In 1998, the USFWS issued a Biological Opinion on the clearing of approximately 80 acres (32.4 ha) of forest habitat on Fort Knox. The USFWS required that tree removal, or at least the removal of all live and dead trees 9 inches (22 cm) dbh or greater, had to be con-ducted between Sept 15 and March 15, to minimize direct mortality to roosting young Indiana bats (USFWS 1998a).

In 1998, the USFWS extended a Biological Opinion on the removal of 246.3 acres (99.7 ha) of suitable Indiana bat summer habitat at Camp Atterbury. The USFWS required the protection of 667 acres (270 ha) as Indiana Bat Management Zones, to be removed from commercial timber rotation and to be managed for Indiana bat conservation. Military activities could not be increased beyond the then-current levels. Also, a landscape-scale forest management policy was requested by USFWS, to provide a sustainable source of suitable summer habitat for the Indiana bat on post. A radio-telemetry study to locate roost trees and characterize habitat around roost trees was also requested (Pruitt 1998).

All installations with documented populations of Indiana bats and active forest management programs comply with the USFWS guidelines for silvicultural practices to conserve the species. These include limitations on sizes and extent of clear-cuts, the removal of large diameters trees, the removal of snags, and protection of waterways from erosion. Details of typical silvicultural restrictions are found in Chapter 6 of this report.

Brief summary of available data related to this issue

Quite a few studies have characterized the general habitat types used by Indiana bats for roosting and foraging during summer months, including composition of forest types used and observations related to roost tree characteristics. To a large degree, habitat choice has been documented in an observational manner, without quantitative methods that compare sites utilized with sites not utilized, or random sites. Menzel et al. (2001) provided a thorough review of the scientific literature related to summer roosting and foraging habitat for the Indiana bat; a complete summary of that effort is beyond the scope of this section. The authors listed the following gaps in knowledge as ongoing research needs related to summer roosting and foraging habitat of the Indiana bat: (1) identification of resources provided by each of the multiple maternity roost trees used by a colony, (2) assessment of the factors affecting maternity roosting behavior, (3) effects of forest management on roosting ecology, (4) assessment of the relationship between forest stand structure, including disturbances and reproductive success, colony behavior, and fitness, (5) quantitative studies of foraging habitat selection through radiotelemetry studies, (6) comparison of vegetation characteristics of points where foraging is documented to occur with vegetative characteristics of random points within the area and, (7) measurement of how much foraging activity occurs over agricultural fields.

It is known that gray bats depend on forest cover for protection from predators during nocturnal emergence and during flight to foraging areas. It is also known that gray bats forage primarily over bodies of water with abundant flying insects. One study quantified distances between the roost cave and foraging sites ranging from 1.2 to 17.3 miles (2 to 27.8 km) (LaVal et al. 1977). Tuttle (1976a) documented that maternity colonies prefer to be within 0.6 miles (1 km) of water, and are rarely found in caves greater than 2.5 miles (4 km) from water.

Documented indications of level of interest from USFWS

In the 1999 agency draft of the Indiana Bat Recovery Plan, the USFWS lists a need for:

- additional study on the food habits and foraging habitat of the Indiana bat,
- the development of quantifiable measures to delineate summer habitat of the Indiana bat,
- characterization of all habitats at the landscape level,
- data to support trend analysis for summer habitat,
- evaluation and improvement of Rommé's 1995 Habitat Suitability Index model.

Research Recommendations

Menzel et al. (2001) reviewed available information regarding Indiana Bat habitat requirements, including summertime roost and foraging habitat, and proposed additional research priorities. The scope of ecological questions related to summer habitat quality range from the specific microhabitat characteristics of Indiana bat maternity roosts to forest community composition and structure to landscape-level patterns that may influence foraging habitat selection. Specific consideration of the military mission suggests that the highest priority for Army research dollars would begin with additional studies at the landscape scale.

Both Camp Atterbury and Fort Knox consulted with the USFWS when construction of new ranges was desired; the projects included conversion of forested habitat over relatively large areas. Such large-scale projects are likely the most significant situation in which the military mission potentially conflicts with the summertime habitat requirements of the Indiana and gray bats. Camp Atterbury is known to support a minimum of 5 maternity colonies of Indiana bats, whereas Fort Knox may support an Indiana bat maternity population, although no pregnant or lactating females have been documented on post to date. Both installations desired to clear forested land to create new training ranges. Camp Atterbury developed Indiana Bat Management Zones to mitigate the loss of likely summer habitat, whereas Fort Knox was not required to take this step. In any case, impacts to Indiana or gray bats could be reduced if landscape-level patterns were understood and considered prior to planning the removal of forested habitat on installations where bats are known or likely to occur in the summertime.

Since Indiana bats tend to forage within a limited space around summertime roost sites, the potential of surrounding habitat to provide food and safety is probably an important, but little understood, factor affecting roost site selection, (in addition to characteristics of individual roost trees). Landscape analyses would be needed to characterize the availability and spatial arrangements of plant communities, roads, waterways, clearings, and human/military land uses within concentric circles of varying diameters around known roost trees and within documented home ranges used for foraging (identified through telemetry studies). Details about plant communities would be important, including community type, age, density of potential roost trees, and structure of the community, including the openness of the understory layer, and canopy height and closure. These analyses should then be compared to analyses of points or polygons that are randomly located across the installation in a study design that will elucidate active selection by Indiana bats for specific landscape elements or patterns. This type of landscape analysis would assist Army planners when new range development is desired. Range location and

planning for mitigation zones can account for landscape characteristics with demonstrated importance to bats.

Maternity colonies of gray bats must roost in cave environments that meet narrow habitat requirements. However, it would be useful to understand the effects of nearby landscape patterns on survival, reproduction, and growth of gray bats in support of gray bat conservation. A similar landscape analysis, as described above, could be conducted for gray bat colonies around known summer roost sites. Landscape characteristics could be compared to estimates of population size, reproductive success, and growth of young and across multiple colonies, to see if any landscape-level characteristics are particularly associated with stress or success in individual colonies. This effort would greatly expand our knowledge about gray bat habitat quality beyond current information regarding the importance of forest cover and proximity to bodies of water.

Further Studies on Summertime Habitat Requirements and Food Supply for the Lesser Long-nosed Bat

Number of installations potentially affected

The species has been documented only on Fort Huachuca, but it may also occur on Florence Military Reservation and Yuma Proving Grounds.

Fort Huachuca offers day roosts, and possibly night roosts, to some portion of a large regional population of the lesser long-nosed bat. Up to 1,439 individuals were counted within a day roost on post in 1993 (USFWS 1999b). Unlike restrictions related to potential noise impacts, which can be in place during the period of bat occupation, protection of foraging resources for the lesser long-nosed bat requires year-round attention.

Number of installations with documented, related restrictions, and nature of restrictions

Fort Huachuca experiences restrictions and additional management burdens relating to the management of Agave Management Areas, to provide a sustainable food supply for the lesser long-nosed bat. The most important consideration is protection of the plants from fire, along with protection from extensive trampling, each of which can affect survival and reproduction of individuals (Howell and Robinett 1996). Restrictions include: no off-road vehicle activity, no pyrotechnics, and no tank training in these areas on the West Range, active suppression of fires unless the fire return interval is approaching the natural interval of 10 years, and reduced

access for dismounted training. Additional land management requirements are in effect for the entire post (73,272 acres [29,653.2 ha]): no planting of non-native grasses or other plants, since such alterations in plant community can affect fire dynamics, a limit of 20 percent mortality to agave populations during intentional fire activities such as prescribed burns, avoidance of off-road vehicular use during fire management activities, avoidance of intensive fire management activity within 0.25 miles (0.4 km) of known day roosts from July 1 through October 31, monitoring of Palmer's agave populations on the West and South ranges, and provide environmental awareness to reduce damage to the bat food supply (USFWS 1999b).

Brief summary of available data related to this issue

The lesser long-nosed bat depends on the nectar and pollen of paniculate agave and columnar cacti during the summer months in which it occurs on Fort Huachuca. Concentrations of these food sources are patchily distributed on the landscape and the nectar and pollen is only seasonally available. Bats travel up to 40 miles (64 km) to opportunistically forage each night. At Fort Huachuca, Palmer's agave and possibly Parry's agave provide food resources. Although these species have evolved with fire, most likely a 10-year return interval, high fire frequency can lead to the decline or elimination of agave populations (Howell 1996).

Documented indications of level of interest from USFWS

The USFWS considers the quantification of the size of foraging areas around roosts as a critical research need for protecting adequate food resources for sustaining this species. USFWS also requests that landscape characteristics, such as the densities of forage plants, and the spatial pattern of bat foraging movements be measured for areas that serve as food supplies. USFWS also requests research related to the effects of human land uses and alteration of plant community dynamics, including the invasion of alien vegetation, on the food resources of this species (all taken from the species' Recovery Plan, USFWS 1997).

In the 1999 Biological Opinion for ongoing mission activities on post, the USFWS requested that Fort Huachuca conduct the following studies: an assessment of the importance of Parry's agave to the local bats, continued investigations related to the fire ecology of the agaves on post, and research related to invasion of Lehmann's lovegrass (*Erogrostis lehmanniana* Nees) and potential means for controlling its invasion on post (USFWS 1999b).

Research Recommendations

It is recommended that continued adaptive management research be conducted on the effects of fire frequency, timing, and intensity on the survival, growth, and reproduction of paniculate agaves on Fort Huachuca.

It is also recommended that a study be undertaken to ascertain the importance of Parry's agave for the species, and an assessment be conducted of how protection of this species may or may not affect the military mission on Fort Huachuca.

It is recommended that a plant community study be completed to ascertain the ecological conditions under which paniculate agaves on post are susceptible to the invasion of Lehmann's lovegrass, and any ecological management techniques that can be used to slow or eliminate its invasion.

Additionally, a large-scale spatial analysis of bat movements through time should be conducted so spatial and temporal restrictions to the mission can be focused more narrowly, if appropriate. This goal might be reached partially through extensive radiotelemetry studies, from which activity on the installation may be determined, as well as possible periods of time in which bats are not utilizing food plants on the installation.

Further Studies on Habitat Requirements for the Hawaiian Hoary Bat

Hawaiian hoary bats have been documented on the property of Keaukaha Military Reservation, Kawailoa Training Area, Makua Military Reservation (one sighting of one bat) and Pohakuloa Training Area. It also potentially occurs on an additional 25 Army and National Guard installations.

Number of installations with documented, related restrictions, and nature of restrictions

According to distribution data within the species recovery plan, the Hawaiian hoary bat does not occur in areas on Makua Military Reservation that are susceptible to accidental fire. If the bat were shown to inhabit relevant areas, management actions designed to minimize the risk of accidental fire in bat habitat would be important. Currently, these actions are already in place for the protection of other threatened and endangered species documented on the installation (USFWS 1999c).

Brief summary of available data related to this issue

The Recovery Plan for the Hawaiian hoary bat states that "Research is the key to reaching the ultimate goal of delisting the Hawaiian hoary bat because currently available information is so limited that even the most basic management actions cannot be undertaken with the certainty that such actions will benefit the subspecies" (USFWS 1998b). Almost any well-designed research project examining basic habitat use, behavior, survival, reproduction, and response to human activities would greatly benefit conservation and management for this species.

Research Recommendations

In the Recovery Plan, the top management priority for eventual delisting of the Hawaiian hoary bat is to "conduct research essential to conservation of the subspecies" (USFWS 1998b). The following requests for research are listed by USFWS:

- develop survey and monitoring protocols,
- develop roosting habitat associations,
- determine the annual natural history cycle,
- determine food habits on Hawaii,
- identify and assess threats.

It is recommended that the Army focus initial research efforts on a comprehensive netting survey combined with radiotelemetry studies for the purpose of identifying habitat use, behavioral patterns (such as foraging behavior), and response to human activities. Results of this research agenda could include data on most effective survey methods, vegetation and physical characteristics of roosting areas, vegetation and physical characteristics of foraging areas, flexibility of individual bats to roost site selection and foraging site selection, and possibly behavioral responses to human activities, including military training activity.

Table 4. Eight proposed research focus areas for further study of endangered bats found on Army lands, the installations that may benefit from each research question, and current known restrictions related to each topic of research.

Research area	Installation	Current Restrictions
Geographic and Temporal Study for Exposure to Threats Beyond Army Lands for the Conservation of Indiana and Gray Bats	Fort Leonard Wood: Three Indiana bats were captured during summer months on Fort Leonard Wood in 1994, establishing the presence of reproductive females and adult males on the installation during summertime. During the same summer, 210 gray bats were captured at 18 of the 52 netting sites. Indiana bats have been documented in four hibernacula within the boundary of Fort Leonard Wood, and within a cave located 5.6 km from the boundary of FLW. Gray bats are not known to hibernate on Fort Leonard Wood (3D/ Environmental 1996a).	none
	Fort Campbell: Two male Indiana bats were captured on Fort Campbell in 1998. Since then, one male was captured in June 2002 (BHE 2002a) and one male was captured in June 2003 (BHE 2003). A Priority I Gray bat hibernaculum is located within 5 miles of the installation boundary (BHE 2004).	none
	Fort Knox: One male Indiana bat has been documented during summer months on Fort Knox. Although it is likely that maternity colonies exist on Fort Knox, none has been documented to date (USFWS 1998a).	none

Research area	Installation	Current Restrictions
	Camp Atterbury: Camp Atterbury, Indiana is thought to provide habitat to at least 5 maternity colonies of Indiana bat, as well as male Indiana bats (Pruitt 1998).	none
	Fort Huachuca: Fort Huachuca offers day roosts, and possibly night roosts, to some portion of a large regional population of the lesser long-nosed bat. Up to 1,439 individuals were counted within a day roost on post in 1993 (USFWS 1999b).	none
	Newport Chemical Depot Newport Chemical Depot, IN has documented at least two maternity colonies of the Indiana bat on site, as well as the presence of an adult male Indiana bats (McWilliams-Munson 1999).	none
	Iowa Army Ammo Plant Two pregnant female Indiana bats were captured at the Iowa Army Ammunition Plant in Iowa during a survey in the summer of 1998 (Tetra Tech EM, Inc. 2001).	none
Further Study on Impacts from Smokes and Obscurants for the Conservation of Indiana and Gray Bats	Fort Leonard Wood: The military mission at Fort Leonard Wood requires relatively frequent, small-scale deployment of smoke pots and smoke grenades. Currently, TPA smoking devices are used at the rate of 141 grenades and 59 pots maximum per day at one or more of 22 training locations (3D/Environmental 1996a).	The use of pots and grenades containing hexachloroethane (HC) has been eliminated. The use of pots and grenades containing TPA is restricted from deployment within 36 meters of any roost trees and within 120 meters of waterways, and to daylight hours only during the summer maternity season.

Research area	Installation	Current Restrictions
	Camp Atterbury: Camp Atterbury utilizes smoke and obscurant materials during summer training exercises. During 2001, an average of 6 M18 smoke grenades, containing terephthalic acid (TPA), were deployed per day between April and September. The 2002 draft biological assessment prepared by Camp Atterbury projected the additional use of 3.3 M83 smoke grenades and an unspecified number of M83 smoke pots would be added to the training exercises. The M83 materials also contain TPA (Pruitt 1998).	The use of pots and grenades containing hexachloroethane (HC) has been eliminated. The use of pots and grenades containing TPA is restricted from deployment within 36 meters of any roost trees and within 120 meters of waterways, and to daylight hours only during the summer maternity season.
	Fort Knox, Fort Campbell, Iowa Army Ammunition Plant, Newport Chemical Depot, Picatinny Arsenal, Crane NSWC, US Military Academy, Jefferson PG, Redstone Arsenal, Fort McClellan, Indiana Army Ammunition Plant, Holston AAP, and Scott AFB (see Table 1): All have documented occurrences of the Indiana bat or gray bat. Importance and extent of use of smokes and obscurants is unknown.	None.
Further Studies on Pesticide Impacts (and other issues related to prey availability) for the Conservation of Indiana and Gray Bats	Newport Chemical Depot: This installation has 35 agricultural leases, 30 of which are row crop leases, for a total of 3,512 acres of agricultural out-lease. Portions of many of these fields lie immediately adjacent to known and potential Indiana bat habitat (McWilliams-Munson 1999).	A 10-meter buffer strip is required between the application of herbicides and forested vegetation. A 20-meter buffer strip is required between the application of insecticides and forested vegetation. Aerial application of pesticides is prohibited. Application of pesticides in gusty wind or when wind speeds exceed 5 mph should be avoided. Ultra low volume and mist applications should be avoided. Non-chemical means of reducing pest population will be employed (McWilliams-Munson 1999).
	Fort Leonard Wood, Camp Atterbury, Iowa Army Ammo Plant, Fort Campbell, Picatinny Arsenal, Crane NSWC, US Military Academy, Jefferson PG, Redstone Arsenal, Fort McClellan, Indi-	None.

Research area	Installation	Current Restrictions
	ana AAP, Holston AAP, Scott AFB and Fort Knox: Have documented summertime occurrences of the Indiana bat or the gray bat. Importance and extent of use of pesticides on these installations is unknown.	
Further Studies on Noise Impacts and General Disturbance Impacts for the Conservation of Indiana, Gray, Hawaiian Hoary and Lesser Long-nosed Bats	Fort Leonard Wood, Fort Campbell, Fort Knox, Fort Huachuca, Camp Atterbury, Fort McClellan and Makua Military Reservation: These installations are known to harbor endangered bat species. These installations provide space for training activities that are likely to involve large numbers of troops, large troop movements, including the use of heavy vehicles and tanks, and the use of large artillery. If noise or other typical military activities, such as the use of low altitude aircraft and/ or bivouacking, is shown to harm endangered bats, these installations are likely to suffer significant restrictions to the training mission.	Fort Leonard Wood restricts activities within a 20 acre (radius of 162 meters) area around each cave known to contain Indiana bats (during hibernation) or a maternity colony of gray bats (summertime). Within the restricted zone, only foot traffic is allowed. No activity is permitted inside the caves. Prohibition of noise extends to a total distance of 1,932 meters radius around each cave (3D/ Environmental 1996a). On Fort Huachuca, night firing of small arms is prohibited on three ranges during the period of July 1 through October 31 each year. Extensive regulations are in place on this installation to minimize the risk of accidental fires and to ensure rapid response in the case of accidental fire, since fires can destroy essential food resources of the lesser long-nosed bat. Areas identified for management as agave management areas are protected in part by exclusion of tracked vehicle access, pyrotechnics and off-road vehicle access in these areas, and active fire management in these areas. From July 1 through October 31, nighttime training of any sort is prohibited in these areas, as well. Rocket-assisted take-offs at one launching areas for unmanned aerial vehicles, the Black Tower launch site, could affect foraging behavior of nearby lesser long-nosed bats. Rocket-assisted, nocturnal launches are prohibited from Black Tower from July through October when the bats are known to be on-post. Low-level helicopter flights

Research area	Installation	Current Restrictions
		are prohibited from July 1 through October 31 within 350 feet of day roosts of the bat (USFWS 1999b).
	Iowa AAP, Newport CD, others: These installations are known to support Indiana bats during the summertime, but are relatively unlikely to generate significant impacts to the bats based on troop activity or weapons firing. Camp Atterbury does support infantry training, but not heavy artillery practice.	Camp Atterbury recognizes that two training areas are covered by more than 68% of their land area in suitable Indiana bat summer habitat, so the installation has determined that military training activities in those two training areas, with a total of 2,845.4 acres, will not increase in intensity. In addition, a total of 777 acres have been designated as Indiana Bat Management Zones as mitigation for the development of a multi-purpose training range on Camp Atterbury; within these areas, military activities are permitted, but off-road maneuvers are minimized and tracked vehicles must stay on existing roads and trails (Tetra Tech, Inc. 2002).
Further Studies on Swarming Biology for the Indiana and Gray Bats	Fort Leonard Wood has four caves within installation boundaries where Indiana bats have hibernated. These would be sites of swarming behavior in the fall, and post-emergence staging in the spring prior to migration (3D/Environmental 1996a). Based on information available to this project at this time, it is not known if other installations contain active hibernacula of Indiana or gray bats.	Three concentric buffer zones have been created around known Indiana bat hibernacula on Fort Leonard Wood. The smallest zone is 20 acres (radius of 162 meters) in size. Activities are limited to foot traffic only. No activity is ever allowed within the cave itself. The first buffer zone extends to a total radius of 457 meters; within this zone, most activities involving smokes and obscurants and noise production are prohibited. The second buffer zone extends to a total radius of 1,932 meters and protects the bats from habitat alteration and noise generation (3D/ Environmental 1996a).
	Two male Indiana bats were captured on Fort Campbell in late August, 1998. Indiana bats have been documented roosting in winter and spring in at least 5 caves within ca. 5 miles of the installation boundary (BHE 2004). It is possible that Fort Campbell may play some role in providing resources to these bats during the swarming period	None

Research area	Installation	Current Restrictions
Further Studies on Summertime Habitat Requirements for the Indiana and Gray Bats	Fort Knox and Camp Atterbury Both have documented occurrences of the Indiana bat on post, and also have proposed major clearing and construction projects that required consultation with the USFWS due to likely impacts to Indiana bat maternity habitat. For Leonard Wood, Iowa Army Ammunition Plant, Fort Campbell, and Newport Chemical Depot: Have documented occurrences of the Indiana bat or gray bat on post, but have not directly consulted with USFWS about planned alterations to summer maternity habitat. If any of these installations desired to clear forested land for development, they would certainly be subject to similar restrictions as documented for Camp Atterbury and Fort Knox.	In 1998, the USFWS extended a Biological Opinion on the clearing of approximately 80 acres of forest habitat on Fort Knox. The USFWS required that tree removal, or at least the removal of all live and dead trees 9 inches dbh or greater, had to be conducted between Sept 15 and March 15, to minimize direct mortality to roosting young Indiana bats (USFWS 1998a). In 1998, the USFWS extended a Biological Opinion on the removal of 99.7 hectares of suitable Indiana bat summer habitat at Camp Atterbury, Indiana. The USFWS required the protection of 270 hectares as Indiana Bat Management Zones, to be removed from commercial timber rotation and to be managed for Indiana bat conservation as well as the then-current levels of military activities. Also, a landscape-scale forest management policy was requested by USFWS, to provide a sustainable source of suitable summer habitat for the Indiana bat on post. A radio-telemetry study to locate roost trees and characterize habitat around roost trees was also requested (Pruitt 1998).
	Fort Knox, Fort Campbell, Camp Atterbury, Newport Chemical Depot, and the Iowa Army Ammo Plant All installations with summer Indiana bat occurrences and forestry programs are subject to restrictions to the means and extent of harvest in order to protect maternity habitat. It is unknown the importance or extent of forestry programs on these installations, but they are all known to provide summer habitat to the Indiana bat.	These include limitations on sizes and extent of clear-cuts, the removal of large diameters trees, the removal of snags, and protection of waterways from erosion. Details of typical silvicultural restrictions are found in Section X.X of this report.
Further Studies on Summertime Habitat Requirements and Food Supply for	Fort Huachuca:	In Agave Management Areas on the West Range, no off-road vehicle activity, no pyrotechnics, and no tank training is allowed; active suppression of fires unless the fire

Research area	Installation	Current Restrictions
the Lesser Long-nosed Bat	Fort Huachuca offers day roosts, and possibly night roosts, to some portion of a large regional population of the lesser long-nosed bat. Up to 1,439 individuals were counted within a day roost on post in 1993 (USFWS 1999b). Unlike restrictions related to noise effects, which can be limited to the season of bat occupation, many restrictions for protection of foraging resources require year-round attention.	return interval is approaching the natural interval of 10 years is required, and access for dismounted training is reduced. Additional land management requirements are in effect for the entire post (73,272 acres): no planting of non-native grasses or other plants, since such alterations in plant community can affect fire dynamics, a limit of 20 percent mortality to agave populations during intentional fire activities such as prescribed burns, avoidance of off-road vehicular use during fire management activities, avoidance of intensive fire management activity within 0.25 miles from known day roosts from July 1 through October 31.
Further Studies of Habitat Requirements for the Hawaiian Hoary Bat	Hawaiian hoary bats have been documented on the property of Keaukaha Military Reservation, Kawailoa Training Area, Makua Military Reservation (one sighting of one bat) and Pohakuloa Training Area, in Hawaii. The species also potentially occurs on many Army National Guard properties.	None.

8 Conclusion

Collectively, endangered bats are widely distributed across Army lands on installations in the east and central United States, the desert southwest, and on the Hawaiian Islands. Their presence creates numerous cases where military land management and training activities are currently, or could potentially be influenced. To date, the Army has altered the timing and location of training, as well as the materials and equipment used in training programs, for the purpose of conserving endangered bat species. Gaining additional information through strategically focused research could alter the type or magnitude of current restrictions on military training, testing and land management.

Literature Cited

3D/Environmental. 1996a. *Biological Assessment of the Master Plan and Ongoing Mission for the U.S. Army Engineer Center and Fort Leonard Wood.* Prepared under contract number DACA41-89-C-0193 for the Kansas City District, U.S. Army Corps of Engineers, Kansas City, MO, dated Feb 21, 1996.

3D/Environmental. 1996b. *Supplement to the Biological Assessment of the Master Plan and Ongoing Mission for the U.S. Army Engineer Center and Fort Leonard Wood.* Prepared under contract number DACA41-89-C-0193 for the Kansas City District, U.S. Army Corps of Engineers, Kansas City, MO, dated May 9, 1996.

Abouhalder, F. 1992. "Influence of livestock grazing on saguaro seedling establishment," pages 57-61 in C.P. Stone and E.S. Bellantoni, eds, *Proceedings of the Symposium on Research in Saguaro National Monument*, Tucson, AZ.

Arizona Game and Fish Department. 2003. Leptonycteris curasoae yerbabuenae. Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. 8 pp.

Baldwin, P.H. 1950. "Occurrence and behavior of the Hawaiian bat." *Journal of Mammology,* 31: 455-456.

Barbour, R.W. and W.H. Davis. 1969. *Bats of America*. University Press of Kentucky, Lexington, KY.

Barclay, R.M.R. 1985. "Long- versus short-range foraging strategy of hoary (*Lasiurus cinereus*) and silver-haired (*Lasionycteris noctivagans*) bats and the consequences for prey selection." *Canadian Journal of Zoology,* 63: 2507- 2515.

Belwood, J.J. 1979. "Feeding ecology of an Indiana bat community with emphasis on the endangered Indiana bat, *Myotis sodalis*." M.S. Thesis, University of Florida, Gainesville, FL.

Belwood, J.J. 2002. "Endangered bats in suburbia: observations and concerns for the future," pp. 193-198 in Kurta, A., and J. Kennedy, eds, *The Indiana bat: biology and management of an endangered species*. Bat Conservation International, Austin TX.

Belwood, J.J. and J.H. Fullard. 1984. "Echolocation and foraging behavior in the Hawaiian hoary bat, *Lasiurus cinereus semotus*." *Canadian Journal of Zoology*, 62: 2113-2120.

Best, T.L., B.A. Milam, T.D. Haas, W.S. Cvilikas, and L.R. Saidak. 1997. "Variation in diet of the gray bat (*Myotis grisescens*)." *Journal of Mammology*, 78: 569-583.

BHE Environmental, Inc. (BHE). 2002a. "Monitoring of Endangered Bats at Fort Campbell, Kentucky and Tennessee, 2002." Unpublished report prepared for the U.S. Army Engineer District, Kansas City, Missouri and submitted to the Fort Campbell Public Works Business Center, Environmental Division, Fort Campbell, KY.

BHE Environmental, Inc. (BHE). 2002b. "Radiotelemetry Study, Endangered Bats, Fort Campbell, Kentucky and Tennessee, 2002." Unpublished report prepared for the U.S. Army Engineer District, Kansas City, Missouri and submitted to the Fort Campbell Public Works Business Center, Environmental Division, Fort Campbell, KY.

BHE Environmental, Inc. (BHE). 2003. "Monitoring of Endangered Bats at Fort Campbell, Kentucky and Tennessee, 2003." Unpublished report prepared for the U.S. Army Engineer District, Kansas City, Missouri and submitted to the Fort Campbell Public Works Business Center, Environmental Division, Fort Campbell, KY.

BHE Environmental, Inc. (BHE). 2004. "Endangered Species Management Plan for the Gray Bat (*Myotis grisescens*) and Indiana bat (*Myotis sodalis*) at Fort Campbell, Kentucky: 2003 Annual Update," Unpublished report prepared for the U. S. Army Engineer District, Kansas City, Missouri and submitted to the Fort Campbell Public Works Business Center, Environmental Division, Fort Campbell, KY.

Bowles, J.B. 1981. *Ecological Studies on the Indiana Bat in Iowa*. Central College, Pella, IA.

Brack, V. and R.K. LaVal. 1985. "Food habits of the Indiana bat in Missouri." *Journal of Mammology*, 66: 308-315.

Britzke, E.R., M.J. Harvey, and S.C. Loeb. 2003. "Indiana bat, *Myotis sodalis*, maternity roosts in the southern United States." *Southeastern Naturalist*, 2: 235-242.

Brown, D.E. 1994. *Biotic Communities- Southwestern United States and Northwestern Mexico*. University of Utah Press, Salt Lake City.

Bryan, E.H., Jr. 1955. "The Hawaiian Bat." *'Elepaio* 15:1-2.

Menard, T.H. 2001. "Activity Patterns of the Hawaiian Hoary Bat ( ) in Relation to Reproodductive time periods" , unpublished Master's Thesis, University of Hawaii, Manoa. Available online at http://www.dofaw.net/fbrp/downloads/pdfs/menard_thesis_2001.pdf.

Callahan, E.V., III. 1993. "Indiana Bat Summer Habitat Requirements." Master of Science Thesis. University of Missouri. Columbia, MO.

Callahan, E.V., R.D. Drobney, and R.L. Clawson. 1997. "Selection of summer roosting sites by Indiana bats (*Myotis sodalis*) in Missouri." *Journal of Mammology*, 78: 818-825.

Cataldo, D., P. Van Voris, M. Ligotke, R. Fellows, B. McVeety, S. Li, H. Bolton, Jr., and J. Frederickson. 1989. *Evaluate and characterize mechanisms controlling trans-port, fate, and effects of Army smokes in an aerosol wind tunnel: transport, transformations, fate and terrestrial ecological effects of fog oil obscurant smokes*. AD-A20414. Pacific Northwest National Laboratory, Richland, WA.

Clark, D.R., Jr. 1986. “Toxicity of methyl parathion to bats: mortality and coordination loss.” *Environmental Toxicology and Chemistry*, 5:191–195.

Clark, B.K., J.B. Bowles, and B.S. Clark. 1987. “Summer occurrence of the Indiana bat, Keen’s Myotis, evening bat, silver-haired bat and eastern pipistrelle in Iowa.” *Proceedings of the Iowa Academy of Science*, 94: 89-93.

Clark, D.R. Jr., R.K. LaVal, and D.M. Swineford. 1978. “Dieldrin-induced mortality in an endangered species, the gray bat (*Myotis grisescens*).” *Science*, 199: 1357-1359.

Clark, D.R., Jr., A. Lollar, and D.F. Cowman. 1996. "Dead and dying Brazilian free-tailed bats (Tadarida brasiliensis) from Texas: rabies and pesticed exposure." Southwestern Naturalist 41: 275-278.

Clark, D.R., Jr., and B.A. Rattner. 1987. “Orthene toxicity to little brown bats (*Myotis lucifugus*): acetylcholinesterase inhibition, coordination loss, and mortality.” *Environmental Toxicology and Chemistry*, 6:705–708.

Clawson, R. 1984. *A determination of the source and effects of pesticide poisoning of gray bats in Boone County, Missouri*. Final Report Federal Aid Project No. W-13-R-38, Study No. 71. Missouri Department of Conservation, Jefferson City, MO.

Clawson, R.L. 2002. “Trends in population size and current status,” pp 2-8 in A. Kurta and J. Kennedy, eds, *The Indiana bat: biology and management of an endangered species.* Bat Conservation International, Austin TX.

Clawson, R.L., R.K. LaVal, M.L. LaVal, and W. Caire. 1980. “Clustering behavior of hibernating *Myotis sodalis* in Missouri.” *Journal of Mammalogy*, 61: 245-253.

Clawson, R.L., R. Titus, D.Figg, L.Burger, C Hauser, T. French, and D. Beffa. 1992. “Management Plan for the Indiana Bat and the Gray Bat in Missouri.” Unpublished report, Missouri Department of Conservation, Jefferson City, MO.

Cockrum, E.L. 1991. “Seasonal distribution of northwestern populations of the long-nosed bats, *Leptonycteris sanborni* Family Phyllostomidae.” Anal. Instit. Biol., Univ. Nac. Autonoma de Mexico, *Ser. Zool*, 60: 181-202.

Cockrum, E.L. and Y. Petryszyn. 1991. *The lesser long-nosed bat. Leptonycteris: An endangered species in the Southwest?* Texas Tech Univ., Occasional Papers of the Museum., Number 142.

Cope, J.B., A.R. Richter, and R.S. Mills. 1974. “Concentrations of the Indiana bat, *Myotis sodalis*, in Wayne County, Indiana.” *Proceedings of the Indiana Academy of Science*, 83: 482-484.

Cope, J.B., A.R. Richter, and D.A. Searly. 1978. A survey of bats in Big Blue Lake project area in Indiana. U.S. Army Corps of Engineers.

Cropek, D. 2003. Toxicological effects of smoke and obscurants on aquatic threatened and endangered species, SERDP Annual Report, FY 03, U.S. Army CERL.

Daily American Republic. 2004. Endangered bat habitat is found in Wayne Co. July 13,2004. Poplar Bluff, MO. http://www.darnews.com/articles/2004/07/13/news/news5.txt

Dalland, J.I. 1965. "Hearing sensitivity in bats." *Science*, 150: 1185-1186.

Dalton, V.M and D.C. Dalton. 1993. "Assessment of the impacts of low level military aircraft on *Leptonycteris curasoae*, an endangered bat, at Organ Pipe Cactus National Monument, Arizona." Unpublished report to Luke Air Force Base, AZ, and Organ Pipe Cactus National Monument, Ajo, AZ.

Dalton, V.M., D.C. Dalton, and S.L. Schmidt. 1994. "Roosting and foraging use of a proposed military training site by the long-nosed bat, *Leptonycteris curasoae*." Unpublished report to the Luke Air Force Natural Resources Program, Contract Nos. DACA65-94-M-0831 and DACA65-94-M-0753.

Dunn, W.E., D.F. Brown, and A. J. Policastro. 1998. "Modeling fog oil smoke dispersion using the SMOKE model." Presented at the Air and Waste Management Associations Federal Facilities Compliance Conference, November, 1998, Washington, DC.

Farmer, A.H., B.S. Cade, and D.F. Stauffer. 2002. "Evaluation of a Habitat Suitability Index model," pp. 172-179 in A. Kurta and J. Kennedy, eds, *The Indiana bat: biology and management of an endangered species*. Bat Conservation International, Austin TX.

Fenton, M.B. and G.P. Bell. 1981. "Recognition of species of insectivorous bats by their echolocation calls." *Journal of Mammology*, 62(2): 233-243.

Fleming, T.H., R.A. Nunez, and L.S.L. Sternberg. 1993. "Seasonal changes in the diets of migrant and non-migrant nectarivorous bats as revealed by carbon stable isotope analysis." *Oecologia*, 94:72-74.

Fullard, J.H. 1989. "Echolocation survey of the distribution of the Hawaiian hoary bat (*Lasiurus cinereus semotus*) on the island of Kauai." *Journal of Mammology*, 70: 424-426.

Garner, J. D., and J. E. Gardner. 1992. *Determination and summer distribution andhabitat utilization of the Indiana Bat (Myotis sodalis) in Illinois.* Illinois Departmentof Conservation. Final Project Report No. E-3. Springfield, IL.

Gardner, J.E., J.D. Garner and J.E. Hofmann. 1989. "A portable mist netting system for capturing bats with emphasis on *Myotis sodalis* (Indiana bat)." *Bat Research News*, 30: 1-8.

Gardner, J.E., J.D. Garner, and J.E. Hofmann. 1990. *Combined Progress Reports: 1989 and 1990 Investigations of Myotis sodalis (Indiana Bat) Distribution, Habitat Use, and Status in Illinois*. Progress Report for United States Department of Interior, Fish and Wildlife Service, Twin Cities Ecological Field Office, Bloomington, MN.

Gardner, J.E., J.D. Garner, and J.E. Hofmann. 1991a. *Summer Roosting Selection and Roosting Behavior of Myotis sodalis (Indiana Bat) in Illinois*. Final Report. Illinois Natural History Survey, Illinois Department of Conservation. Champaign, IL.

Gardner, J.E., J.D. Garner, and J.E. Hofmann. 1991b. *Summary of Myotis sodalis Summer Habitat Studies in Illinois: with Recommendations for Impact Assessment*. Special Report. Illinois Natural History Survey, Illinois Department of Conservation. Champaign, IL.

Gentry, H.S. 1982. *Agaves of Continental North America*. Univ. of Arizona Press, Tucson.

Getz, L.L., K.A. Reinbold, D.J. Tazik, T.J. Hayden, and D.M. Cassells. 1996. *Preliminary Assessment of the Potential Impact of Fog Oil Smoke on Selected Threatened and Endangered Species*. Technical Report 96/38 ADA306219, U.S. Army Construction Engineering Research Laboratory.

Goebel, A. B. (1996). "Temporal variation in movement patterns of adult female *Myotis grisescens* (Chiroptera: Vespertilionidae)," M.S. thesis, Auburn University, Auburn, AL.

Gore, J.A. 1992. "Gray bat," pages 63-70 in S.R. Humphrey, ed., *Rare and Endangered Biota of Florida*. University Presses of Florida, Gainesville.

Grue, C.E., P.L. Gilbert, and M.E. Seeley. 1997. "Neurophysiological and behavioral changes in nontarget wildlife exposed to organophosphate and carbamate pesticides: thermoregulation, food consumption, and reproduction." *American Zoologist*, 37: 369–388.

Hall, J.S. 1962. "A life history and taxonomic study of the Indiana bat, *Myotis sodalis*." *Reading Public Museum and Art Gallery, Science Publication* 12:1-68.

Hayward, B., and E.L. Cockrum. 1971. "The natural history of the western long-nosed bat, *Leptonycteris sanborni. West. New Mexico University Research Science*, 1:75-123.

Hobson, C.S. and J.N. Holland. 1995. "Post-hibernation movement and foraging habitat of a male Indiana bat, *Myotis sodalis* (Chiroptera: Vespertilionidae) in Western Virginia." *Brimleyana*, 23: 95-101.

Hoffman, D.J., B.A. Rattner, G.A. Burton, Jr., and J. Cairns, Jr. 1995. *Handbook of Ecotoxicology*. CRC Press, Boca Raton, FL.

Hoffmeister, D.F. 1986. *Mammals of Arizona*. University of Arizona Press, Tucson.

Horner, M.A., T.H. Fleming, and M.D. Tuttle. 1990. "Foraging and movement patterns of a nectar feeding bat: *Leptonycteris curasoae*." *Bat Research News*, 31:81.

Howell, D.J. 1996. "*Agave palmeri* on Fort Huachuca: Five Years of Research on Natural History and Response to Fire." Final Report to Fort Huachuca, AZ.

Howell, D.J. and D.G. Robinett. 1996. "Agave Management Plan." Report to the Environment and Natural Resources Division, Fort Huachuca, AZ.

Hoyt, R.A., J.S. Altenbach, and D.J. Hafner. 1994. Observations on long-nosed bats (Leptonycteris) in New Mexico. Southwestern Naturalist 39:175-179.

Humphrey, S.R. 1978. "Status, winter habitat, and management of the endangered Indiana bat, *Myotis sodalis*." *Florida Scientist*, 41:65-76.

Humphrey, S.R., A.R. Richter, and J.B. Cope. 1977. "Summer Habitat and Ecology of the Endangered Indiana Bat, *Myotis sodalis*." *Journal of Mammalogy*, 58: 334-346.

Jacobs, D.S. 1993a. "Foraging behavior of the endangered Hawaiian hoary bat, *Lasiurus cinereus semotus*." Final report to the U.S. Fish and Wildlife Service (Grant 14-48-0001-92570).

Jacobs, D.S. 1993b. "Character release in the endangered Hawaiian hoary bat, *Lasiurus cinereus semotus*. Ph.D. Dissertation, University of Hawaii, Honolulu, HI.

Jacobs, D.S. 1994. "Distribution and abundance of the endangered Hawaiian hoary bat, *Lasiurus cinereus semotus*." *Pacific Science*, 48: 193-200.

Kepler, C.B. and J.M. Scott. 1990. "Notes on distribution and behavior of the endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*), 1964-1983." *'Elepaio*, 50(7):59-64.

Kiser, J.D and C.L. Elliot. 1996. *Foraging habitat, food habits, and roost tree character-istics of the Indiana bat (Myotis sodalis) during autumn in Jackson County, Kentucky*. Final report E-2, Kentucky Department of Fish and Wildlife Resources, Frankfort, KY.

Kramer, R.J. 1971. *Hawaiian Land Mammals*. Charles E. Tuttle, Rutland, VT.

Kujioka, K.K. and S.M. Gon III. 1988. "Observations of the Hawaiian bat (*Lasiurus cinereus semotus*) in the districts of Ka'a and south Kona, island of Hawaii." *Journal of Mammology*, 69: 369- 371.

Kunz, T.H. 1982. "Roosting ecology," pp 1-46 in T.H. Kunz, ed., *Ecology of Bats*. Plenum Press, New York.

Kurta, A. 1980. "Status of the Indiana bat, *Myotis sodalis*, in Michigan." *Michigan Academician*, 13:31-36.

Kurta, A., D. King, J.A. Teramino, J.M. Stribley, and K.J. Williams. 1993. "Summer roosts of the endangered Indiana bat (*Myotis sodalis*) on the northern edge of its range." *American Midland Naturalist*, 129: 123-138.

Kurta, A., K.J. Williams, and R. Mies. 1996. "Ecological, behavioral and thermal observations of a peripheral population of Indiana bats (*Myotis sodalis*), pp. 102-117 in R.M.R. Barclay and R.M. Brigham, eds., *Bats and Forests Symposium*, Working Paper 23, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia, Canada.

Kurta, A. and J.O. Whitaker, Jr. 1998. "Diet of the endangered bat (*Myotis sodalis*) on the northern edge of its range." *American Midland Naturalist*, 140: 280-286.

Kurta, A., and S. W. Murray. 2002. "Philopatry and migration of banded Indiana bats (*Myotis sodalis*) and effects of radio transmitters." *Journal of Mammalogy*, 83: 585-589.

Kurta, A., S.W Murray and D. Miller. 2002. "Roost selection and movements across the summer landscape." In, Kurta, A., and J. Kennedy (eds.) *The Indiana Bat: Biology and Management of an Endangered Species*. Bat Conservation International, Austin, Texas.

LaVal, R.K. and M.L. LaVal. 1980. *Ecological studies and management of Missouri bats, with emphasis on cave-dwelling species*. Terrestrial Series 9, Missouri Department of Conservation, Jefferson City, MO.

LaVal, R.K., R.L. Clawson, W. Claire, L.R. Wingate, and M.L. LaVal. 1976. *An evaluation of the status of Myotine bats in the proposed Meramec Park Lake and Union Lake project areas, Missouri*. Unpublished Final Report to the U.S. Army Corps of Engineers, St Louis, MO. 136 pp.

LaVal, R.K., R.L. Clawson, M.L. LaVal, and W. Claire. 1977. "Foraging behavior and nocturnal activity patterns of Missouri bats, with emphasis on the endangered species *Myotis grisescens* and *Myotis sodalis*." *Journal of Mammology*, 58: 592-599.

Lee, Y. F. 1993. "Feeding ecology of the Indiana bat, *Myotis sodalis*, and resource partitioning with *Myotis keenii* and *Myotis lucifugus*". Unpubl. M.S. Thesis, Univ. of Tennessee, Knoxville, TN.

Liljegren, H., W.E. Dunn, G.E. DeVaull. 1988. *Field Study of Fog Oil Smokes*, U.S. Army Medical Research and Development Command, Fort Detrick, MD.

Liljegren, J.C., W.E. Dunn, G.E. DeVaull, and A. Policastro. 1989. *Field measurement and model evaluation program for assessment of the environmental effects of military smokes: field study of fog-oil smokes*. ADA205344. Argonne National Laboratory, Argonne, IL.

McFarland, C.A. 1998. "Potential Agricutural Insecticide Exposure of Indiana Bats (Myotis sodalis) in Missouri." M.S. thesis, University of Missouri, Columia, Missouri.

McFarland, C.A. and R. Drobney. 1978. "Potential agricultural insecticide exposure of Indiana bats (*Myotis sodalis*) in Missouri." M.S. Thesis. University of Missouri- Columbia, Columbia, MO.

McKenzie, P.M. 1999. "Biological Opinion on the Impacts of Forest Management and Other Activities to the Gray Bat, Bald Eagle, Indiana Bat, and Mead's Milkweed on the Mark Twain National Forest, Missouri." Report submitted to the U.S. Forest Service, June 23, 1999 from the U.S. Fish and Wildlife Service, Columbia, MO.

McWilliams-Munson, R. 1999. "Biological Opinion on the Agricultural Pesticide Application Practices at the Newport Chemical Depot, Newport, Indiana." Report submitted to the Department of the Army, April 13 1999. Bloomington Field Office, U.S. Fish and Wildlife Office.

Menard, T. 2001. "Activity Patterns of the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) in relation to Reproductive Time Periods." M.S. Thesis for the Graduate Division of the University of Hawai'i. Honolulu, HI.

Menzel, M.A., J.M. Menzel, T.C. Carter, W.M. Ford, and J.W. Edwards. 2001. *Review of the forest habitat relationships of the Indiana bat (Myotis sodalis)*, General Technical Report NE-284, Northeastern Research Station, USDA Forest Service, Newtown Square, PA.

Menzel, J.M., Menzel, M.A., Ford, W.M., Carter, T.C., Gardner, J.E., Garner, J.D., and J.E. Hoffmann. 2005. Summer habitat use and home-range analysis of the endangered Indiana bat. *Journal of Wildlife Management* 69: 430-436.

Miller, N.E. 1996. "Indiana bat summer habitat patterns in northern Missouri." Unpublished Master's thesis, University of Missouri-Columbia, Columbia, MO.

Miller, N.E., R.D. Drobney, R.L. Clawson, and E.V. Callahan. 2002. "Summer habitat in northern Missouri." Pp. 165-171 in A. Kurta and J. Kennedy, eds, *The Indiana bat: biology and management of an endangered species*. Bat Conservation International, Austin TX.

Mitchell, W.A. 1998. *Species Profile: Gray Bat (Myotis grisescens) on Military Installa-tions in the Southeastern United States*, U.S. Army Waterways Experiment Station Technical Report SERDP-98-6 (March 1998).

Montgomery Watson and 3D/International. 1998. "Biological Assessment: Effects to Indiana Bats and Bald Eagles from Construction and Operation of the Proposed Multi-Purpose Training Range, Atterbury Reserve Forces Training Area, Edinburgh, Indiana." Report prepared for Military Department of Indiana.

Nicholson, K.W. 1995. "Physical aspects of bioaerosol sampling and deposition," pp. 27-53 in C. Cox and C. Wathes, eds, *Bioaerosols Handbook*, Lewis Publishers, Boca Raton, FL.

O'Shea, T. J., and D. R. Clark. 2001. Overview of impacts of contaminants on bats: with special reference to the Indiana bat. Bat Research News 42: 36.

Policastro, J.J., D.M. Maloney, W.E. Dunn, J.C. Liljegren and G.E. DeVaull. 1989. *Evaluation of Atmospheric Dispersion Models for Fog-oil Dispersion.* U.S. Army Medical Research and Development Command, Fort Detrick, MD.

Potts, S.F. 1946. "Particle size of insecticides and its relationship to application distribution and deposits." *Journal of Economic Entomology*, 39: 716- 720.

Potts, S.F. 1959. "Equipment for pest and disease control." *Unasylva*, 13: 1-18.

Pruitt, L.B. 1998. *Biological Opinion on the Construction and Operation of the Multi-purpose Training Range (MPTR) at the Camp Atterbury Army National Guard Training Site, Edinburgh, Indiana*, Bloomington Field Office, U.S. Fish and Wildlife Service, Bloomington, Indiana, December 4, 1998.

Racey P. A. 1982. "Ecology of bat reproduction." Pp.57–104, in T. H. Kunz, ed., *Ecology of bats*, Plenum Press, New York.

Reist, P.C. 1993. *Aerosol science and technology*, Second Edition, McGraw-Hill, Inc. New York, NY.

Reynolds, M.H., B.C. Cooper, and R.H. Day. 1997. "Radar study of seabirds and bats on windward Hawai'i." *Pacific Scientist*, 51: 97-106.

Reynolds, M.H., B.M. Neilson, and J.D. Jacobi. 1997/1998. "Surveys of the Hawaiian Hoary Bat in the district of Puna, Hawaii'Island." *'Elepaio*, 57: 153-157.

Richter, A. R., S. R. Humphrey, J. B. Cope, and V. Brack, Jr. 1993. "Modified cave entrances: thermal effect on body mass and resulting decline of endangered Indiana bats (*Myotis sodalis*)." *Conservation Biology*, 7:407-415.

Rommé, R. C., K. Tyrell, and V. Brack, Jr. 1995. *Literature Summary and Habitat Suitability Index Model: Components of Summer Habitat for the Indiana Bat, Myotis sodalis*. Report submitted to the Indiana Department of Natural Re-sources, Division of Wildlife, Bloomington, IN.

Rommé, R., C. Henry, A. B. King, R. A., Glueck, T. and Tyrell, K. 2002. Home range near hibernacula in spring and autumn. In, Kurta, A., and J. Kennedy (eds.) The Indiana Bat: Biology and Management of an Endangered Species. Bat Conservation International, Austin, Texas.

Rubinoff, J., S. Sekscienski, and B. Woodson. 2003. Installation Summaries From the 2003 Survey of Threatened and Endangered Species. Army Environmental Center Technical Report SFIM-AEC-TS-TR-2004005. 21 pp. plus appendices.

Sahley, C.T., M.A. Horner, and T.H. Fleming. 1993. "Flight speeds and mechanical power outputs in the nectar feeding bat, *Leptonycteris curasoae* (Phyllostomidae: Glossophaginae)." *Journal of Mammalogy*, 74:594-600.

Schmidt, U. and G. Joermann. 1986. "The influence of acoustical interferences on echolocation in bats." *Mammalia*, 50: 379-389.

Schmidt, A. C., K. Tyrell, and T. Glueck. 2002 "Environmental contaminants in bats collected from Missouri." In, Kurta, A., and J. Kennedy (eds.) *The Indiana Bat: Biology and Management of an Endangered Species.* Bat Conservation International, Austin, Texas.

Shimozawa, T., N. Suga, P. Hendler, and S. Schuetze. 1974. "Directional sensitivity of echolocation system in bats producing frequency-modulated signals." *Journal of Experimental Biology*, 60: 53-69.

Sidner, R. 1999. "Ninth annual monitoring report of bats, especially the lesser long-nosed bat (*Leptonycteris curasoae*), with emphasis upon roost sites on the Fort Huachuca Military Reservation, Cochise County, Arizona, May - October 1998." Report to Fort Huachuca, AZ. Contract #DABT63-98-T-0093.

Slauson, L. 1996. "Pollination ecology of *Agave chrysantha* and *Agave palmeri*," pp 154-203 in *Amorphametric and Pollination Ecology Study of Agave chrysantha Peebles and Agave palmeri Englem. (Agavaceae).* Ph.D. Diss., Arizona State University, Tempe, AZ.

Slauson, L. 2000. "Pollination biology of two chiropterophilous agaves in Arizona," *American Journal of Botany*. 87: 825-836.

Smith, T. in prep. Screening Level Ecological Risk Assessments for Selected Threatened and Endangered Species. DRAFT technical report, U.S. Army Engineer Research and Development Center, Construction and Engineering Research Laboratory, Champaign, IL.

Stinson, E. and P. Bromley. 1991. *Pesticides and Wildlife: a Guide to Reducing Impacts on Animals and their Habitat*. Virginia Department of Game and Inland Fisheries, Publication 420-004.

Stoner, K.E., Karla A. O.-Salazar, Roxana C. R.-Fernández and Mauricio Quesada. 2003. "Population dynamics, reproduction, and diet of the lesser long-nosed bat (*Leptonycteris curasoae*) in Jalisco, Mexico: implications for conservation." *Biodiversity and Conservation*. 12: 357-373.

Strenge, D. and C. Driver. 2003. "Methods for assessing the impact of fog oil on availability, palatability and food quality of relevant life stages of insect food sources for TES," presentation at the SERDP in-progress review meeting, April 2-4, 2003, Washington, D.C.

Suthers, R.A. 1970. "Vision, olfaction, taste," pp 265-309 in W.A.Winsatt, ed., *Biology of Bats, Volume II*. Academic Press.

Tefler, T.C. 1992. "Survey of the Hawaiian bat on the island of Kauai and selected areas statewide," Unpublished report, Hawaii Division of Forestry and Wildlife.

Tetra Tech Inc. 2001. *Endangered Species Management Plan and Environmental Assessment for the Indiana Bat, Myotis sodalis, Iowa Army Ammunition Plant, Des Moines County, Iowa.* Report to Mobile District, U.S. Army Corps of Engineers.

Tetra Tech, Inc. 2002. *Biological Assessment: Effects to Indiana Bats from Ongoing and Anticipated Future Military Activities*. Report to Camp Atterbury, IN. Contract # DACW01-99-D-0029.

Thomas, D.W., M. Dorais, and J.M. Bergeron. 1990. "Winter energy budgets and cost of arousals for hibernating little brown bats (*Myotis lucifugus*)." *Journal of Mammology*, 71: 475-479.

Tomich, P.Q. 1986a. "Endangered species information system species workbook. Part I- species distribution." Unpublished U.S. Fish and Wildlife Service Report.

Tomich, P.Q. 1986b. *Mammals in Hawaii*. Bishop Museum Press, Honolulu, HI.

Tuttle, M.D. 1976a. "Population Ecology of the Gray Bat (*Myotis grisescens*): Factors Influencing Growth and Survival of Newly Volant Young." *Ecology*, 57:587-595.

Tuttle, M.D. 1976b "Population Ecology of the Gray Bat (*Myotis grisescens*): Philopatry, Timing, and Patterns of Movement, Weight Loss During Migration, and Seasonal Adaptive Strategies." Occasional Papers of the Museum of Natural History, University of Kansas, Lawrence, KS.

Tuttle, M.D. 1979. "Status, causes of decline, and management of endangered gray bats." *Journal of Wildlife Management*, 43:1-17.

Tuttle, M.D. and D.M. Stevenson. 1977. "An analysis of migration as a mortality factor in the gray bat based on public recoveries of banded bats." *American Midland Naturalist*, 97: 235-240.

Tuttle, M. D. and D. E. Stevenson. 1978. "Variation in the Cave Environment and Its Biological Implications," pp108-121 in R. Juber, et al., eds, *National Cave Management Symposium Proceedings*. Speleobooks Adobe Press, Albuquerque, NM.

Tuttle, M. D. and D. E. Kennedy. 2002. "Thermal requirements during hibernation," pp68-78 in Kurta, A.and J, Kennedy, eds, *The Indiana Bat: Biology and Management of An Endangered Species*. Bat Conservation International, Austin, Texas.

U.S. Fish and Wildlife Service (USFWS). 1982. *Gray Bat Recovery Plan*. Prepared by the U.S. Fish and Wildlife Service in cooperation with the Gray Bat Recovery Team, Atlanta, GA.

USFWS. 1997. *Lesser long-nosed bat recovery plan*. Albuquerque, NM.

USFWS. 1998a. *Biological Opinion on the Effects to the Endangered Indiana Bat of Construction of a Qualification Training Range at Fort Knox, Hardin County, Kentucky*, October 1998.

USFWS. 1998b. *Recovery Plan for the Hawaiian Hoary Bat (Lasiurus cinereussemotus).* Portland, OR.

USFWS. 1999a. Agency Draft: *Indiana Bat (Myotis sodalis) Revised Recovery Plan*. Fort Snelling, MN.

USFWS. 1999b. *Fort Huachuca Programmatic (10-year) Biological Opinion*, prepared by the Arizona Ecological Services Field Office of the U.S. Fish and Wildlife Service, Albuquerque, NM, October 27, 1999.

USFWS. 1999c. *Biological Opinion of the Fish and Wildlife Service for Routine Military Training at Makua Military Reservation*, prepared by the Pacific Islands Ecoregion Office of the U.S. Fish and Wildlife Service, Honolulu, HI, July 23, 1999.

USFWS. 1999d. *Biological Opinion on the Impacts of Forest Management and Other Actiities to the Gray Bat, Bald Eagle, and Indian Bat, and Mead's Milkwed on the Mark Twain National Forest, Missouri*, prepared by the U.S. Fish and Wildlife Service, Columbia, MO, June 23, 1999.

USFWS. 1999e. Biological Opinion on Impacts of Continued Forest Management Activities in the Ouachita National Forest, prepared by the U.S. Fish and Wildlife Service, Tulsa OK, April 26, 1999.

USFWS. 2001. *Biological Opinion on the Land and Resource Management Plan, Wayne National Forest, Ohio*, prepared by the U.S. Fish and Wildlife Service, Reynoldsburg, OH, September 20, 2001.

USFWS. 2003. *Revised Biological Opinion of the Fish and Wildlife Service for Proposed and Ongoing Activities by the Marine Corps Air Station-Yuma in the Arizona portion of the Yuma Training Range Complex on the Barry M. Goldwater Range, Yuma and Maricopa Counties, AZ*, prepared by the U.S. Fish and Wildlife Service, Phoenix, AZ, August 6, 2003.

USFWS. 2004. Forest Management Guidelines for Areas Within Five Miles of Priority I and II Hibernacula for Indiana Bats (*Myotis sodalis*). Bloomington, Indiana.

Whitaker, J.O., Jr. 1972. "Food habits of bats from Indiana." *Canadian Journal of Zoology*, 50: 877-883.

Whitaker, J.O., Jr. and P.Q. Tomich. 1983. "Food habits of the hoary bat, *Lasiurus cinereus*, from Hawaii." *Journal of Mammology*, 64: 151-152.

Whitaker, J.O., Jr. and V. Brack. 2002. "Distribution and summer ecology in Indiana," pp 48-54 in A. Kurta and J. Kennedy, eds, *The Indiana bat: biology and management of an endangered species*. Bat Conservation International, Austin TX.

Wilson, D.E. 1985. *Status report: Leptonycteris sanborni Hoffmeister, Sanborn's long-nosed bat.* U.S. Fish and Wildlife Service, Denver Wildlife Research Center, National. Museum Natural History, Washington DC.

Young, J., D. Smart, J. Allen, D. Parmer, A. Rosencrance, E. Brueggeman, and F. Broski. 1989. *Field exposure of chemical school students and cadre to fog oil and hexachloroethane (HC) smokes*. Technical Report 8908, U.S. Army Biomedical Research and Development Laboratory, Fort Detrick, Frederick, MD.

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14. ABSTRACT

The Indiana bat, gray bat, lesser long-nosed bat, and Hawaiian hoary bat are all protected as endangered species throughout their ranges within the United States. One or more of these species has been documented to occur on at least 19 installations where the Army trains. This report evaluates the potential for these four endangered bat species to impact military training activities, based on species conservation requirements, training requirements, and documented restrictions put in place by the U.S. Fish and Wildlife Service. This report includes basic information about each species' life requirements, occurrences on or near Army lands, known training restrictions that have been instituted in support of species conservation, and a brief risk analysis of the potential for development of new data leading to additional future restrictions. Based on the risk analysis, this report recommends research priorities for the Army that would improve the scientific basis for evaluating the risk of military training to these species, and thus, the risk of species conservation impacting Army preparedness.

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